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Standards of Performance for the control of emissions of volatile organic compounds from flexible vinyl coating and printing operations are being proposed under the authority of Section 111 of the Clean Air Act. The standard would apply to flexible vinyl printing lines for which construction or modification began on or after the date of proposal of the regulation. This document contains background information and environmental and economic impact assessments of the regulatory alternatives considered in developing the proposed standard.

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Emission Standards and Engineering Division

U.S ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

January 1983

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft
Environmental Impact Statement
for the Flexible Vinyl
Coating and Printing Industry

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1. The proposed standards of performance would limit emissions of volatile organic compounds (VOC) from new, modified, and reconstructed flexible vinyl coating and printing facilities. Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare." The northeastern and north central regions of the country would be particularly affected by the proposed standards.

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.

3. The comment period for review of this document is 60 days. Mr. Gene W. Smith may be contacted regarding the date of the comment period.

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TABLE OF CONTENTS

Chapter Page

1 SUMMARY 1-1
1.1 Regulatory Alternatives 1-1
1.2 Environmental Impact 1-2
1.3 Economic Impacts 1-6

2 INTRODUCTION 2-1
2.1 Background and Authority for Standards 2-1
2.2 Selection of Categories of Stationary Sources . 2-5
2.3 Procedure for Development of Standards of Performance 2-7
2.4 Consideration of Costs 2-9
2.5 Consideration of Environmental Impacts 2-10
2.6 Impact on Existing Sources 2-11
2.7 Revision of Standards of Performance 2-12

3 THE FLEXIBLE VINYL COATING AND PRINTING INDUSTRY PROCESS AND POLLUTANT EMISSIONS 3-1
3.1 Background 3-1
3.2 FVC&P Product Processes and Emissions 3-1
3.2.1 Introduction 3-1
3.2.2 Raw Material Receiving and Storage . . . 3-4
3.2.3 Substrate Preparation 3-4
3.2.4 Web Formation 3-5
3.2.5 Finishing Operations 3-14
3.2.6 Embossing 3-23
3.3 Baseline Emissions 3-24
3.3.1 State and Local Emission Regulations . . 3-24
3.3.2 Selection of the Baseline Emission Level. 3-31
3.4 References 3-32

4 EMISSION CONTROL TECHNIQUES 4-1
4.1 Volatile Organic Compound Control 4-3
4.1.1 Carbon Adsorption 4-3

TABLE OF CONTENTS (Continued)

Chapter Page

4.1.2 Incineration 4-14
4.1.3 Wet Scrubbing 4-23
4.1.4 Condensation Systems 4-30
4.1.5 Vapor Collection System 4-33
4.2 References 4-41
5 MODIFICATION AND RECONSTRUCTION 5-1
5.1 Modifications 5-1
5.1.1 Changes in Web Width 5-3
5.1.2 Changes in Line Speed 5-3
5.1.3 Changes in the Hours Available for Operation and/or Scheduling Efficiency . 5-4
5.2 Reconstruction 5-5
5.3 References 5-7
6 MODEL PLANTS AND REGULATORY ALTERNATIVES 6-1
6.1 Model Plants 6-1
6.1.1 Model Plant Parameters. 6-3
6.2 Regulatory Alternatives 6-6
6.2.1 Regulatory Alternative I. 6-9
6.2.2 Regulatory Alternative II 6-9
6.2.3 Regulatory Alternative III. 6-9
6.2.4 Controlled Model Plant Parameters 6-10
6.3 References 6-15
7 ENVIRONMENTAL AND ENERGY IMPACTS 7-1
7.1 Air Pollution Impacts 7-2
7.1.1 Primary Air Pollution Impacts 7-2
7.1.2 Secondary Air Pollution Impacts 7-6
7.2 Water Pollution Impacts 7-7

TABLE OF CONTENTS (Continued)

Chapter | Page

7.3 Solid Waste Impacts 7-12
7.4 Energy Impacts 7-16
7.5 Other Environmental Impacts 7-23
7.6 References 7-25
8 COSTS 8-1
8.1 Cost Analysis of Regulatory Alternatives . 8-1
8.1.1 New Facilities 8-2
8.1.2 Modified and Reconstructed Facilities 8-13
8.2 Other Cost Considerations 8-13
8.3 References 8-15
9 ECONOMIC ANALYSIS 9-1
9.1 Industry Profile 9-1
9.1.1 General Industry Characteristics . . 9-1
9.1.2 Firm Characteristics 9-7
9.1.3 Industry Trends 9-8
9.1.4 Growth Projections 9-20
9.2 Economic Impacts Analysis 9-21
9.2.1 Introduction 9-21
9.2.2 Potential Economic Impacts 9-31
9.3 Potential Socioeconomic and Inflationary Impacts 9-42
9.4 References 9-43
APPENDIX A A-1
APPENDIX B B-1
APPENDIX C C-1
APPENDIX D D-1
APPENDIX E E-1
APPENDIX F F-1

LIST OF TABLES

Table | | Page
1-1 Matrix of Environmental and Economic Impacts of Regulatory Alternatives 1-3
3-1 FVC&P Products and End Uses 3-2
3-2 Estimate of Uncontrolled Web Formation Emissions for an Average FVC&P Plant 3-13
3-3 Estimate of Uncontrolled FVC&P Emissions for an Average Plant 3-21
3-4 Existing State Regulations on Emissions of Volatile Organic Compounds Applicable to the Vinyl Coating and Printing Industry 3-25
3-5 Summary of CTG Document for Coating of Fabric and Vinyl 3-29
3-6 Summary of CTG Document for Graphic Arts-Rotogravure and Flexography 3-30
4-1 Range of Capture Velocities 4-35
4-2 Coefficients of Entry for Selected Hood Openings . . . 4-37
6-1 Model Plants 6-2
6-2 Model Plant Parameters for Vinyl Coating Processes . . 6-5
6-3 Model Plant Parameters 6-7
6-4 Annual Production, Land, and Utility Requirements (Without Control Devices) 6-8
6-5 Summary of Regulatory Alternatives 6-11
6-6 Control Option Parameters - Finishing Operation . . . 6-12
6-7 Land and Utility Requirements for Model Plant Control Systems 6-13
7-1 Estimated National VOC Emissions from New Flexible Vinyl Printing Lines 7-3

LIST OF TABLES (Continued)

Table Page

7-2 Air Emission Impacts of the Regulatory Alternatives on the Model Plants 7-5

7-3 Wastewater Discharge Impacts of the Regulatory Alternatives on the Model Plants 7-10

7-4 Estimated National Wastewater Discharge Impacts from VOC Control Systems 7-11

7-5 Estimated National VOC Loading of VOC Control System Wastewater Streams 7-13

7-6 Solid Waste Impacts of the Regulatory Alternatives on the Model Plants 7-14

7-7 Estimated National Solid Waste Impacts from VOC Control Systems 7-17

7-8 Electricity Impacts of the Regulatory Alternatives on the Model Plants 7-18

7-9 Estimated National Electricity Impacts from VOC Control Systems 7-19

7-10 Fuel Oil Impacts of the Regulatory Alternatives on the Model Plants 7-21

7-11 Estimated National Fuel Oil Impacts from VOC Control Systems 7-22

7-12 Net National Energy Impacts of VOC Control 7-24

8-1 Model Plants 8-3

8-2 Bases for Annualized Cost Estimates 8-4

8-3 Installed Capital and Annualized Costs for Uncontrolled Model Plants ($1980) 8-7

8-4 Annualized Costs for VOC Control Systems 8-10

8-5 Annualized Costs for Controlled Model Plants 8-11

9-1 Value of Shipments and Total Quantity Produced in the FVC&P Industry: 1977 9-2

LIST OF TABLES (Continued)

Table		Page
9-2	Companies Which Constitute the Majority of Production in the Flexible Vinyl Coating and Printing Industry	9-4
9-3	Trends in Concentration: 1972-1977	9-9
9-4	Value of Shipments of Supported Vinyl Materials (excluding wall coverings) for Various End-Uses	9-10
9-5	Value of Shipments of Unsupported Vinyl Film . .	9-11
9-6	Value of Shipments of Wall Coverings	9-13
9-7	Percentage Distribution of End-Use Markets for FVC&P	9-14
9-8	Producer Price Index for Polyvinyl Chloride (PVC) Resin: 1971-1979	9-16
9-9	Exports and Imports of FVCP as Percentage of Total Industry Output	9-17
9-10	Prices of FVC&P	9-18
9-11	Estimated Annual Production and Revenues for the Flexible Vinyl Coating and Printing Model Plants	9-23
9-12	Gross Profit Margins for the Major Manufacturers of PVC Coated Fabrics and Films	9-24
9-13	Operating Profit Margins for the Major Manufacturers of PVC Coated Fabrics and Films	9-25
9-14	Net Profit Margins for the Major Manufacturers of PVC Coated Fabrics and Films	9-26
9-15	Net Profits to Assets Ratio for the Major Manufacturers of PVC Coated Fabrics and Films .	9-27
9-16	Summary Financial Ratios for the 65 Percent VOC Control Level (Baseline Case)	9-29
9-17	ROI Analysis of the 65 Percent VOC Control Level (Baseline)	9-33
9-18	ROI Analysis of the 75 Percent VOC Control Level	9-34

LIST OF TABLES (Continued)

Table		Page
9-19	ROI Analysis of the 85 Percent VOC Control Level	9-35
9-20	Debt Service Coverage Analysis	9-38
9-21	Percent Increases in CMLTD	9-39
9-22	Fifth Year Annualized Costs of Compliance for the Worst Case	9-41

LIST OF FIGURES

Figure Page

3-1 Flow Diagram of a Representative Vinyl Coating and Printing Plant 3-3

3-2 Calendering Method of Web Formation 3-6

3-3 Cast Line Producing Supported Vinyl Sheet 3-8

3-4 Two Methods of Applying Coating to Fabric 3-9

3-5 Extrusion of Web 3-11

3-6 Typical Rotogravure Finishing Line with Embosser . . 3-15

3-7 Two-Roll Direct Rotogravure Coating Process 3-16

4-1 Schematic of Two-Bed Adsorber Units: Adsorber 1 Adsorbing, Adsorber 2 Regenerating 4-4

4-2 Schematic of Two-Bed Adsorber Unit: Adsorber 1 Regenerating, Adsorber 2 Adsorbing 4-5

4-3 Schematic of Solvent Recovery by Condensation and Distillation 4-7

4-4 Typical Effect of Operating Temperature on Effectiveness of Thermal Afterburner for Destruction of Hydrocarbons and Carbon Monoxide 4-15

4-5 Incineration with Primary and Secondary Heat Recovery 4-17

4-6 Schematic Diagram of a Catalytic Incinerator 4-18

4-7 Typical Packed Column Scrubber 4-25

4-8 Common Packings Used in Packed Column Scrubbers . . 4-26

4-9 Diagram of a Two Stage, Cross Flow Packed Scrubber . 4-29

4-10 Diagram of an Inert Gas Condensation Solvent Recovery System 4-32

4-11 Typical Method of Recycling VOC-Laden Air Back to the Drying Oven 4-39

LIST OF FIGURES (Continued)

Figure Page

6-1 Finishing Line Model Plant 6-4

7-1 Schematic of the Water Cycle in a FVC&P Plant Solvent Recovery System 7-9

8-1 Estimated Installed Capital Costs for Model Plant Control Systems 8-8

9-1 Geographical Locations of Vinyl Coating and Printing Operations in the United States 9-3

9-2 Production Hierarchy for the Flexible Vinyl Coating and Printing Industry 9-6

1. SUMMARY

1.1 REGULATORY ALTERNATIVES

This Background Information Document (BID) supports proposal of the Federal Regulation for limiting volatile organic compounds (VOC) vapor emissions from the flexible vinyl printing industry. New Source Performance Standards (NSPS) or standards of performance for new, modified, and reconstructed flexible vinyl printing lines are being proposed under Section 111 of the Clean Air Act (42 United States Code 7411). The source of the VOC emissions are the organic solvent components in the inks as well as any other solvent used at the print line, for example, the solvent added to inks for viscosity control.

The three regulatory alternatives considered are presented in Chapter 6. These alternatives call for an overall reduction of gaseous VOC emissions from a fininshing line of 65 percent, 75 percent and 85 percent. The 65 percent control level, Regulatory Alternative I, is defined as baseline control. It represents the VOC emission level that would be allowed if no new source performance standard were promulgated and is based on the control level recommended by EPA's Control Techniques Guidelines document for packaging rate gravure operations. The 65 percent level represents a system which captures 70 percent of the total gaseous VOC emitted from the flexible vinyl printing operation and recovers or destroys 95 percent of these emissions.

Regulatory Alternative II is based on an overall VOC emission reduction from the print line of 75 percent. The control system for Alternative II would capture 80 percent of the total gaseous VOC emitted from the finishing operation and then recover or destroy 95 percent of those emissions. Similarly, Regulatory Alternative III is based on an 85 percent reduction resulting from 90 percent capture and 95 percent recovery or destruction.

All three regulatory control levels can be achieved with the installation of control equipment. Fixed-bed carbon adsorption is the most popular method currently used to control VOC emissions from this industry.

The industry is developing waterborne inks that will meet VOC emission limits without requiring control devices. Chapter 3 includes a discussion of the development of waterborne inks. In the inks being developed, the mass of VOC to mass of ink solids ratio ranges from 0 to 0.75.

1.2 ENVIRONMENTAL IMPACT

Detailed discussions of the environmental impacts associated with the three regulatory alternatives are presented in Chapter 7.

An overview of the potential environmental impacts that could result from the implementation of the regulatory alternatives is presented in Table 1-1. The estimated effects shown in this table are based on comparisons between Regulatory Alternatives II and III and the base case (Regulatory Alternative I). The impacts represent changes above or below the baseline regulatory alternative. No absolute impacts are shown for any alternatives.

Regulatory Alternative I represents the base case. Because of this, all of the impact values for this alternative are zero. There would be no impact in comparing the baseline with itself. Under Regulatory Alternatives II and III, increased reductions in VOC emissions, above that achievable by Alternative I, would be expected. The reductions would increase because the capture system efficiency under Alternative II is higher than the efficiency used in Alternative I. The same control device efficiency was assumed for all three regulatory alternatives.

The primary environmental impact from the flexible vinyl printing industry is the uncontrolled emission of VOC from finishing line drying ovens. The uncontrolled emission of VOC results primarily from the vaporization of solvents in the drying ovens. These drying ovens are used to evaporate the solvents from the inks used in the finishing operations. A varying percentage of solvent vaporizes as fugitive emissions around the rotogravure print head and from the wet web as it travels to the oven.

TABLE 1-1. MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS OF REGULATORY ALTERNATIVES

Administrative Action	Air Impact	Water Impact	Solid Waste Impact	Energy Impact	Noise Impact	Economic Impact
Alternative I 65 percent control	0	0	0	0	0	0
Alternative II 75 percent control	+2**	-1*	-1*	+1**	0	-1*
Alternative III 85 percent control	+3**	-2*	-1*	+2**	0	-1*
Delayed Standards	0	0	0	0	0	0

KEY

+	Beneficial impact
-	Adverse impact
*	Short-term impact
**	Long-term impact
***	Irreversible impact

0 - No impact
1 - Negligible impact
2 - Small impact
3 - Moderate impact
4 - Large impact

VOC emissions can potentially cause an air pollution problem because they are precursors to the formation of ozone and oxygenated organic aerosols (photochemical smog).

VOC emissions from new, modified, or reconstructed flexible vinyl printing lines were estimated on a national basis for the years 1983 to 1987. Under Regulatory Alternative I, in 1987, emissions from new plants would be approximately 1400 megagrams (1600 tons). Regulatory Alternative II would reduce emissions from new plants to 1000 megagrams (1100 tons) in 1987. The strictest level of proposed NSPS control, Alternative III, would reduce VOC emissions in 1987 to 610 megagrams (670 tons) per year. The incremental impact of Alternative II on the baseline control case (Alternative I) would be to reduce national VOC emissions from flexible vinyl printing finishing operations by an additional 30 percent in 1987. In 1987, Alternative III would reduce national VOC emissions from flexible vinyl printing operations by 57 percent more than that achievable under Alternative I.

Table 1-1 indicates that Regulatory Alternatives II and III are likely to cause negligible or small adverse impacts in terms of water quality and solid wastes. The operation of carbon adsorption control devices produces wastewater containing dissolved organics. On a national basis in the year 1987, the total quantities of wastewater produced under Alternative II would be 15 percent above the wastewater generated by Alternative I. Similarly, Alternative III would generate 35 percent more wastewater than Alternative I. In addition the operation of carbon adsorbers also generates some waste carbon. Total quantities of solid waste generated on a national basis in the year 1987 show a 15 percent increase from Alternative I to Alternative II and a 30 percent increase from Alternative I to Alternative III. Wastewater and solid waste impacts should decrease as waterborne inks begin to replace inks containing organic solvents.

The emission control equipment for the flexible vinyl printing industry utilizes electrical energy and steam. Net national energy savings are possible in this industry when the energy value of the recovered solvent is considered. If all new flexible vinyl printing lines built through 1987 were controlled to the level of Regulatory Alternative I, the gross national energy demand would be equal to about 48,000 GJ (45 billion Btu). The amount of solvent potentially recoverable under Alternative I (baseline) control could be translated into about 83,000 GJ (78 billion Btu) of energy. There is a net energy savings in 1987 of 35,000 GJ (33 billion Btu) under this baseline level of control.

Under Regulatory Alternative II control the gross national energy demand would approach 55,000 GJ (52 billion Btu) in 1987. Alternative II control would recover an energy equivalent of 95,000 GJ (90 billion Btu). The net energy impact under Alternative II control, in 1987, would be an energy savings of 40,000 GJ (38 billion Btu). The gross national energy demand under Alternative III would equal approximately 64,000 GJ (61 billion Btu). The higher control efficiency of this alternative would yield a potential solvent recovery equivalent to 105,000 GJ (100 billion Btu) of energy. The net energy impact under Alternative III control, in 1987, would be an energy savings of 41,000 GJ (39 billion Btu).

The incremental energy savings of Alternative II compared to Alternative I would equal 5,000 GJ (5 billion Btu). Alternative III would have a potential energy savings of 6,000 GJ (6 billion Btu) when compared to Alternative I. The favorable national energy impact is important because of the lessening supply and increasing cost of petroleum raw materials.

The impact of increased noise levels is not a significant problem within the emission control systems of the flexible vinyl printing industry. No noticeable increases in noise levels occur as a result of increasingly stricter regulatory alternatives. Motors and solvent-laden air fans are responsible for the majority of the noise in VOC control systems.

1.3 ECONOMIC IMPACTS

An analysis of potential economic effects of the three regulatory alternatives was made based on the model plants described in Chapter 6. A detailed discussion of the economic analysis is present in Chapter 9. The large solvent recovery credits more than offset the costs of control in four of the five model plants. The expected worst-case maximum price impact is only 0.05 percent. No major impacts are expected on geographical regions or local governments.

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be able to see the information considered by EPA in the development of the proposed standard.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereinafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . . the degree of emission reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance.

1. EPA is required to list the categories of major stationary sources that have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

   a. 25 percent of the listed categories by August 7, 1980.
   b. 75 percent of the listed categories by August 7, 1981.
   c. 100 percent of the listed categories by August 7, 1982.

A governor of a State may apply to the Administrator to add a category not on the list or may apply to the Administrator to have a standard of performance revised.

2. EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

3. EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

4. The term "standards of performance" is redefined, and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low- or non-polluting process or operation.

5. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any non-air-quality health and environmental impacts, and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations where some states may attract industries by relaxing standards relative to other states. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal-burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term Best Available Control Technology (BACT), as defined in the Act, means

> ". . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from, or which results from, any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques

> for control of each such pollutant. In no event shall application of "best available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Sections 111 or 112 of this Act. (Section 169(3))."

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions, high concentrations for short periods during filling and low concentrations for longer periods during storage, and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, Section 111(j) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require or an equivalent reduction at lower economic energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to the public health, welfare, or safety; (4) the governor of the State where the source is located consents; and (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to three years to to meet the standards with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Adminstrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such list if in his judgement it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants emitted by stationary sources. Source categories that emit these pollutants are evaluated and ranked by a process involving such factors as: (1) the level of emission control (if any) already required by State regulations, (2) estimated levels of control that might be required from standards of performance for the source category, (3) projections of growth and replacement of existing facilities for the source category, and (4) the estimated incremental amount of air pollution that could be prevented in a preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or under development during 1977, or earlier, were selected on these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions that each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases it may not be feasible immediately to develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inablility to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may vary from insignificant to very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the non-air-quality health and environmental impacts, and the energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering, (2) analysis of the information, and (3) development of the standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from many other sources, and a literature search is conducted. From the knowledge acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the Background Information Document (BID). The BID, the standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As a part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, D. C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the "preamble" of a "promulgation package," which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of (1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance, (2) the potential inflationary or recessionary effects of the regulation, (3) the effects the regulation might have on small business with respect to competition, (4) the effects of the regulation on consumer costs, and (5) the effects of the regulation on energy use. Section 317 also requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and in terms of the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is necessary because both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the economic impact from the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court established a narrow exemption from NEPA for EPA determination under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section in this document is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the general provisions of Subpart A of 40 CFR Part 60, which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under Section 111 (d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator ". . . shall, at least every four years, review and, if appropriate, revise . . ." the standards. Revisions are made to assure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive, but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. THE FLEXIBLE VINYL COATING AND PRINTING INDUSTRY PROCESS AND POLLUTANT EMISSIONS

3.1 BACKGROUND

The industry producing flexible vinyl coated and printed (FVC&P) products coats and prints continuous vinyl webs primarily with solvent solutions of polyvinyl chloride (PVC) resins. Other resins such as urethanes and acrylics can also be used on the same equipment to produce similar products. Almost all of the FVC&P products are produced as a continuous web thicker than two mils. Hand printing processes and dipping processes are not included in the FVC&P industry as defined in this study. Resilient flooring processes are somewhat similar to the FVC&P processes but overall the flooring industry is quite different and will be considered for a separate NSPS.

A variety of FVC&P products for many end uses are manufactured by the industry and most of these are identified in Table 3-1. These products are produced in approximately one hundred plants which are located in the industralized states. Growth in the FVC&P industry is mixed. The real dollar value of shipments of several major product lines are declining while the value of shipments in other areas is increasing. These trends are discussed in detail in Chapter 9 and the effect of these negative and positive trends on emission estimates is described in the next section. Major raw materials are fabric substrates, pigments, PVC, plasticizers and solvents.

3.2 FVC&P PRODUCT PROCESSES AND EMISSIONS

3.2.1 Introduction

The major processes used to produce FVC&P products are web formation, finishing and embossing. These processes are modified in a variety of ways to provide different types of products to satisfy the needs of many end uses. These processes are summarized in Figure 3-1 and described in

TABLE 3-1. FVC&P PRODUCTS AND END USES[a]

SUPPORTED SHEET	UNSUPPORTED SHEET
Wallcovering	Shower Curtains
Products for Automobile Industry	Shades
Roof Headlining	Sheet for lamination to substrates such as -
Landau Roofs	Furniture
Upholstery	Fabric
Door Panels	Ceiling Tile
Seat Belts	
Furniture Upholstery	
Umbrellas	
Window Awnings	
Leatherette	
Gloves	
Shoe Uppers	
Luggage	
Athletic Items	
Marine Items	

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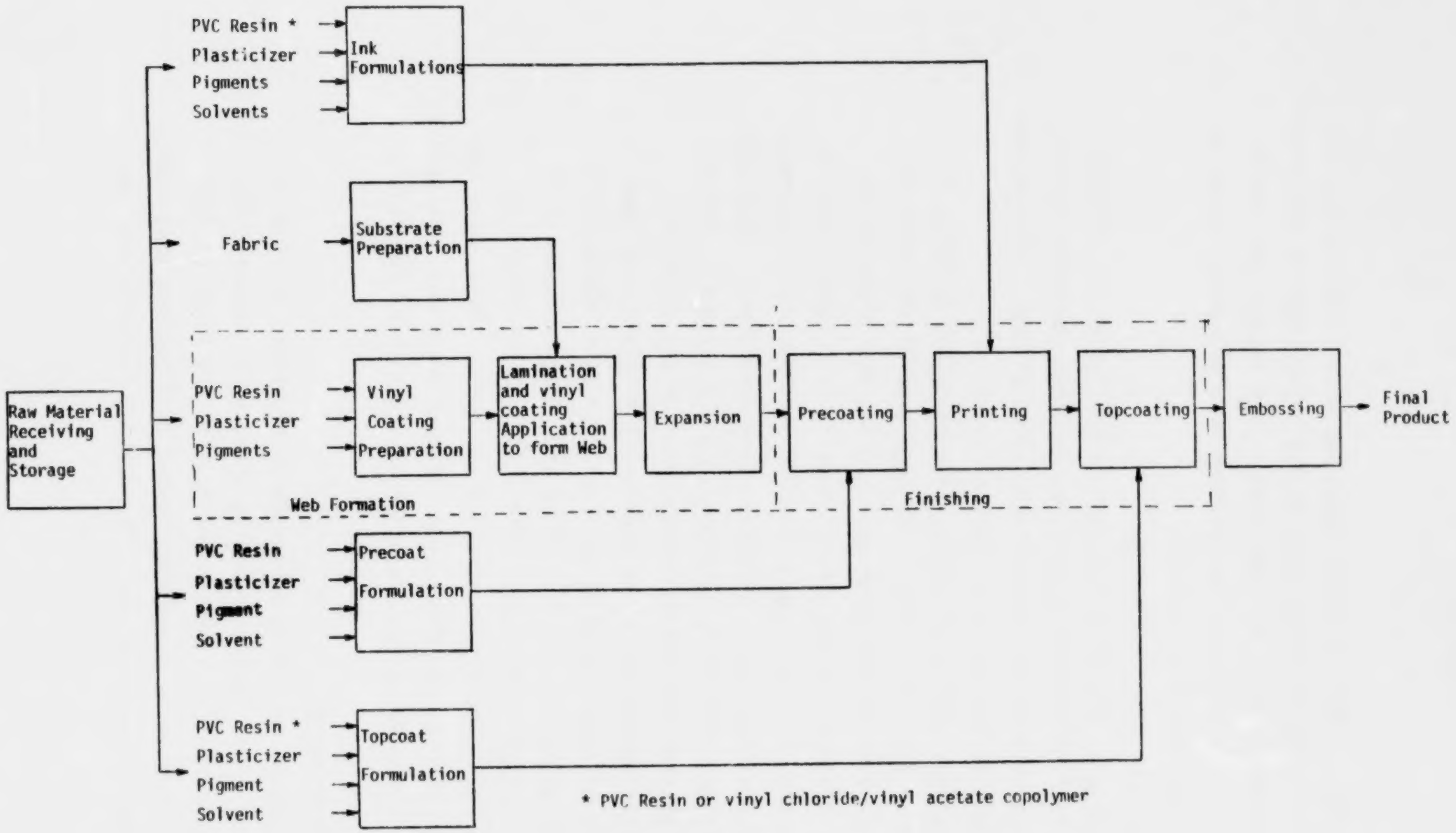
[a] As described in Section 3.2.4, supported sheet has a substrate, usually fabric, whereas unsupported sheet does not have such a substrate.


Raw Material Receiving and Storage
PVC Resin *
Plasticizer
Pigments
Solvents
Ink Formulations
Fabric
Substrate Preparation
PVC Resin
Plasticizer
Pigments
Vinyl Coating Preparation
Lamination and vinyl coating Application to form Web
Expansion
Web Formation
Precoating
Printing
Topcoating
Finishing
Embossing
Final Product
PVC Resin
Plasticizer
Pigment
Solvent
Precoat Formulation
PVC Resin *
Plasticizer
Pigment
Solvent
Topcoat Formulation

* PVC Resin or vinyl chloride/vinyl acetate copolymer

Figure 3-1. FLOW DIAGRAM OF A REPRESENATIVE VINYL COATING AND PRINTING PLANT

the following sections.[1] Many of these steps may be omitted for any one product. In the following sections, each of these processes is described and emissions are characterized and quantified. The figures and tables of Chapter 3 summarize the information obtained by a telephone survey of the FVC&P industry and nine plant visits.

3.2.2 Raw Material Receiving and Storage.

3.2.2.1 Processes. Raw materials such as PVC resins are shipped in 40 to 50 pound bags or handled in bulk by fluidized conveying equipment. Other dry ingredients are shipped and stored in bags. Plasticizer and solvents are shipped and stored in bulk or drums.

3.2.2.2 Emissions. There are particulate emissions involved in the handling of materials such as PVC. The magnitude of the emissions is influenced by the size of the resin particle and the design of the material handling equipment. There are no industry data quantifying the extent of these particulate emissions. The VOC emissions occur wherever solvents are mixed, transported or stored in open containers. Generally there are VOC emissions throughout the receiving and storage operation.

Uncontrolled particulate and VOC emissions from the materials receiving and storage operations of an average FVC&P plant have been estimated at 4.5 Mg (5 tons) to 18 Mg (20 tons) per year respectively. If the point source emissions are over 45 Mg (50 tons) per year or if the emissions are visible, particulate emissions from new plants or major modifications are generally controlled by states. Most state and local agencies have regulations for solvent storage emissions. Therefore, raw material and storage emissions are not being considered for this NSPS.

3.2.3 Substrate Preparation

3.2.3.1 Processes. A fabric substrate is purchased for use in most FVC&P products. This substrate may be woven or non-woven. The substrate provides mechanical strength and bulk to the FVC&P product.

This fabric substrate is frequently heated by a radiant heat source as it enters the web preparation step. The heating controls moisture and assists in establishing a good bond between the substrate and the first coat of vinyl.

3.2.3.2 Emissions. No significant emissions are involved in substrate preparation.

3.2.4 Web Formation

3.2.4.1 Processes. Web formation includes the processes which form the PVC resins, stabilizers, pigments and plasticizers into a continuous vinyl sheet, termed a web. As indicated in Section 9.1 there is excess capacity in the web preparation processes and therefore very few or no new plants or production lines are expected in the web preparation processes.

The web formation process consists of vinyl coating preparation, vinyl coating application to form the web, and sometimes expansion of the web. This vinyl sheet or web may be unsupported or supported by fabric. If the web is unsupported there may also be a step which involves lamination of the vinyl to a fabric backing. The four major techniques used to form the web are:

- calendering,
- casting followed by coating with knife or roll,
- coating with knife or roll, and
- extrusion.

These processes may be varied and combined as discussed below.

The calendering process is described in Figure 3-2. There are no production figures available but it is thought that more than one-half the FVC&P products are manufactured from a calendered web.[2] As indicated in Figure 3-2 the PVC resins, plasticizers, and pigments are blended together in a series of blenders, Banbury mixers and 2-roll mills. After mixing, the charge is conveyed to the calender. In an "inverted L, 4-roll" type calender, the molten vinyl coating is roll-formed into a continuous vinyl sheet. Most calendered products are embossed at this point with a matte finish or other special finish by compression between textured rollers. If the vinyl sheet is to be supported, then it is also applied to a continuous sheet of fabric by compression between the

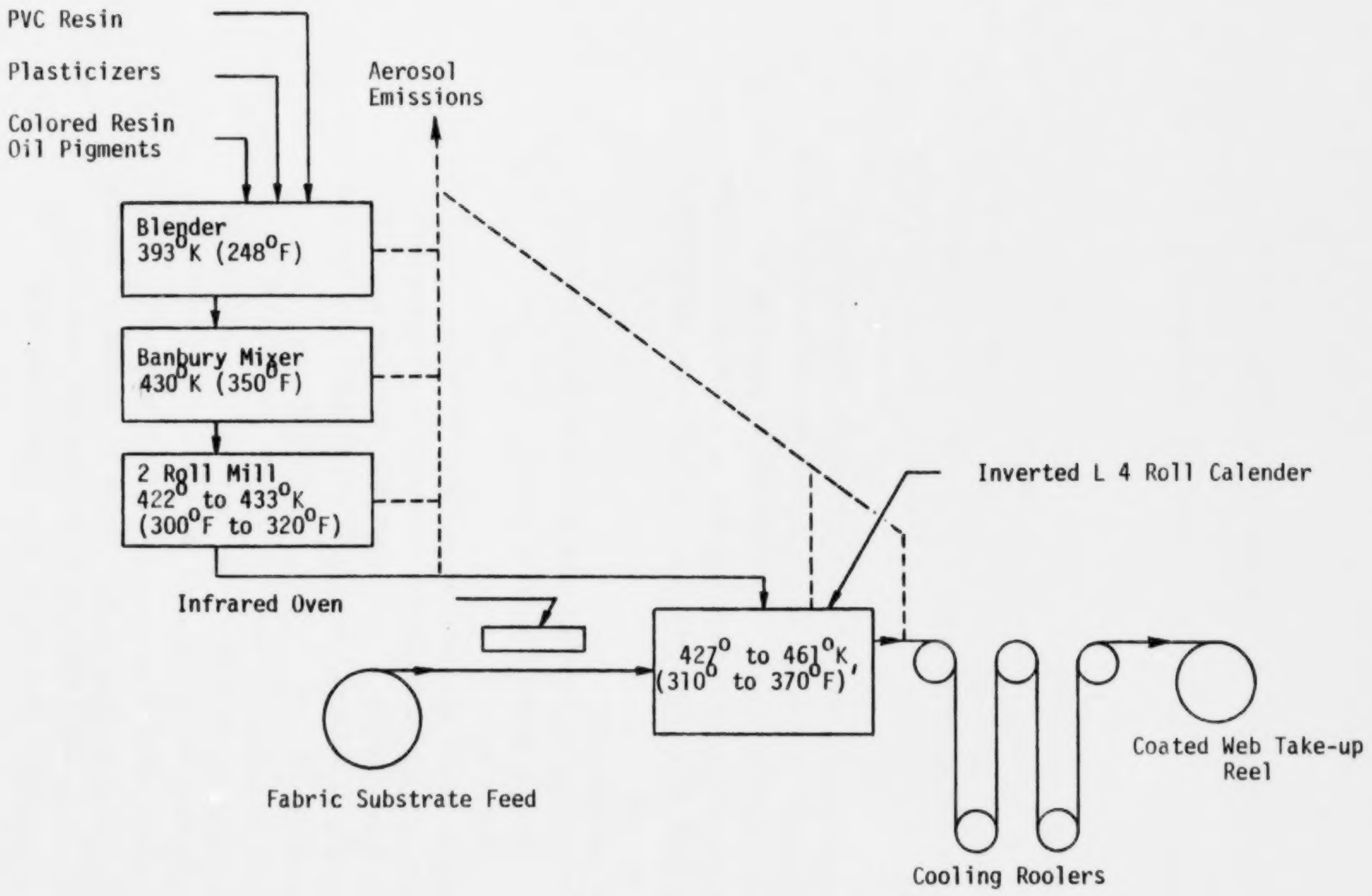

PVC Resin
Plasticizers
Colored Resin
Oil Pigments
Aerosol
Emissions
Blender
393°K (248°F)
Banbury Mixer
430°K (350°F)
2 Roll Mill
422° to 433°K
(300°F to 320°F)
Infrared Oven
Inverted L 4 Roll Calender
427° to 461°K,
(310° to 370°F)
Fabric Substrate Feed
Coated Web Take-up
Reel
Cooling Roolers

Figure 3-2. CALENDERING METHOD OF WEB FORMATION

bottom roller and the support roller to form a supported product. The supported or unsupported web is then cooled.

The advantages of the calendering process over other methods of web preparation are high production rate, low labor and material costs, and very accurate thickness control.

The disadvantages of the calendering process are high capital costs and very stringent temperature control requirements. Again no production figures are available. But it is thought that nearly one-half of the FVC&P products require the web to be formed by casting or coating.

In the casting process a vinyl web is cast or coated onto a paper carrier web using processes such as roll coating and knife coating. This paper is ultimately removed and reused. The vinyl web surface which was next to the paper becomes the finished product surface. The paper carrier may impart a mirror like finish or a textured surface to this vinyl web. If supported sheet is being produced, as shown in Figure 3-3, a fabric web is bonded to the vinyl web in subsequent processes.

Advantages of the casting process include: lower capital costs, the ability to make short runs of specialty items, and an ability to texture the first coat to provide premium quality and a smooth glossy surface (thus eliminating an embossing step). Disadvantages of the process are higher priced raw materials, higher labor cost than the calender process, and casting paper is a high cost component and must be reused.

In a typical coating process the web is formed by coating the substrate, using any one or more coating methods. The two most common methods of coating a substrate are knife over roll and reverse roll. These methods are shown in Figure 3-4 and discussed below.

> Knife Coaters. A tray or trough containing the plastisol coating is located behind the knife blade. A continuous sheet of fabric or paper is drawn between the knife blade and a support roller. As coating is deposited on the sheet, the knife blade spreads it across the fabric to the desired thickness.

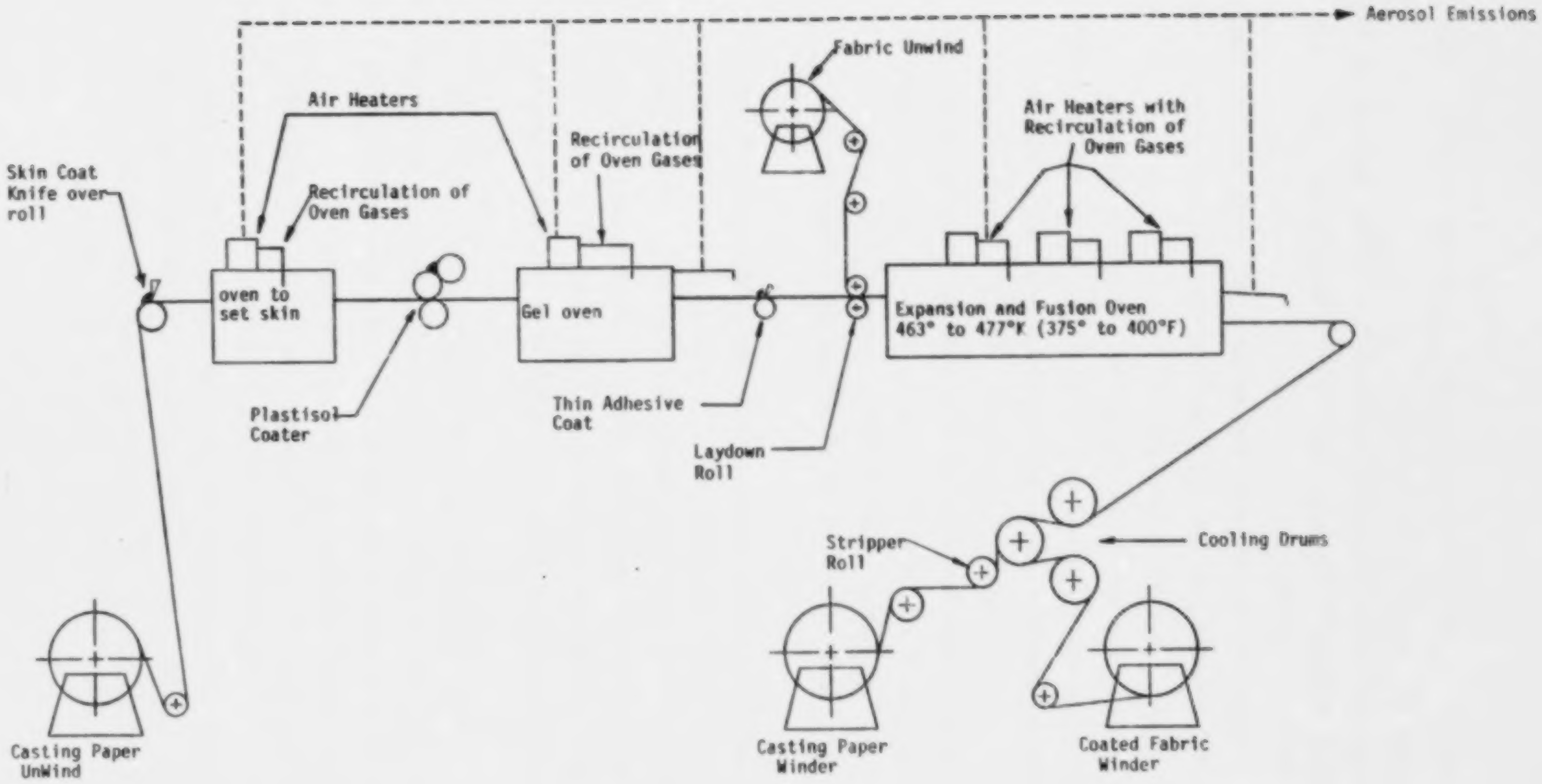
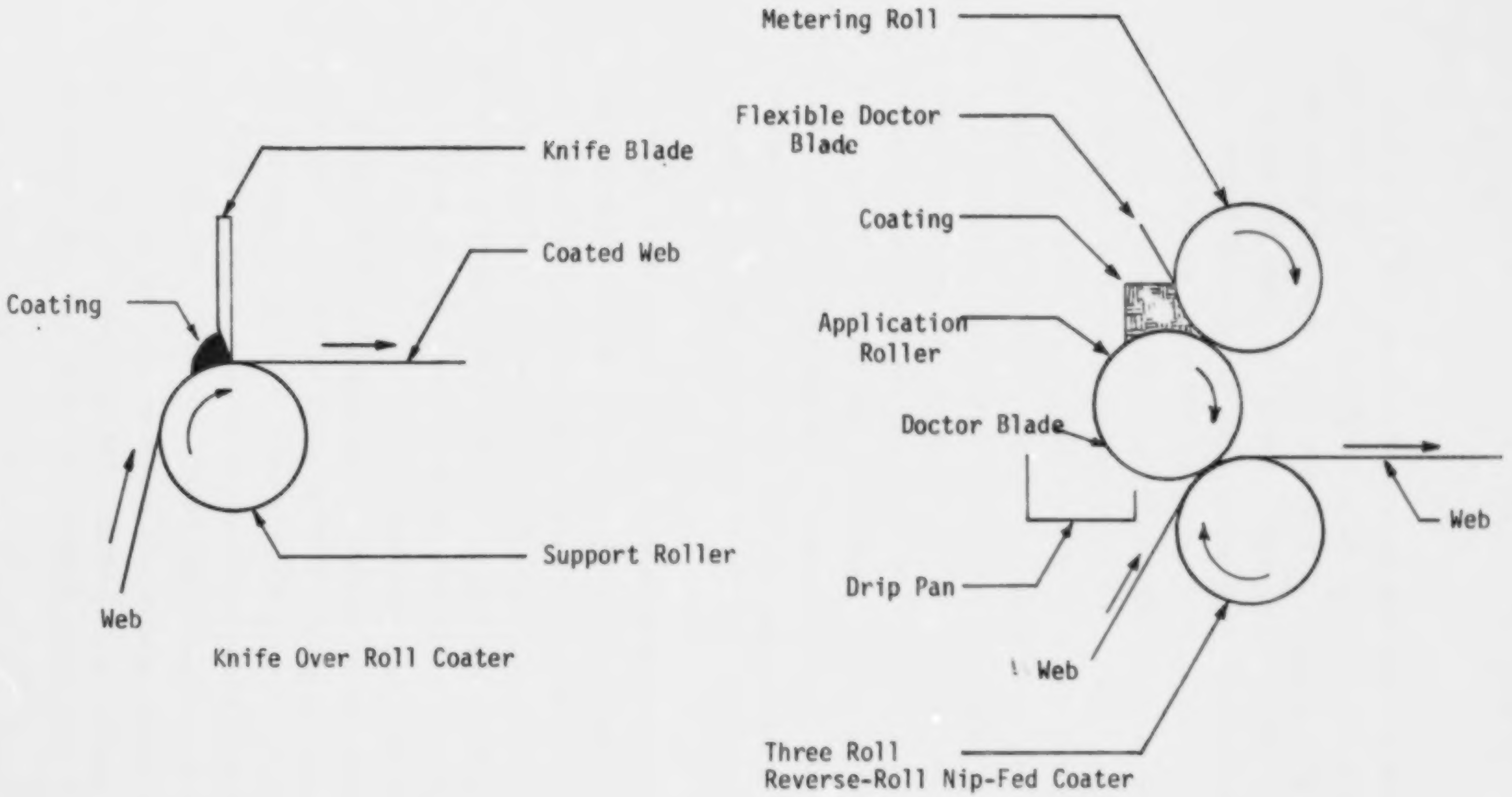

Aerosol Emissions
Skin Coat Knife over roll
Air Heaters
Recirculation of Oven Gases
oven to set skin
Plastisol Coater
Recirculation of Oven Gases
Gel oven
Thin Adhesive Coat
Laydown Roll
Fabric Unwind
Air Heaters with Recirculation of Oven Gases
Expansion and Fusion Oven 463° to 477°K (375° to 400°F)
Cooling Drums
Stripper Roll
Casting Paper UnWind
Casting Paper Winder
Coated Fabric Winder

Figure 3-3. CAST LINE PRODUCING SUPPORTED VINYL SHEET


Knife Blade
Coated Web
Coating
Support Roller
Web
Metering Roll
Flexible Doctor Blade
Coating
Application Roller
Doctor Blade
Drip Pan
Web
Web

Knife Over Roll Coater

Three Roll Reverse-Roll Nip-Fed Coater

Figure 3-4. TWO METHODS OF APPLYING COATING TO FABRIC

The coated web then passes through an oven similar to that shown in Figure 3-3 for fusion of this vinyl to the substrate.

Reverse-Roll Coaters. Figure 3-4 illustrates the three roll, nip-fed, reverse-roll coater. Basically, there are three component rollers: the metering roller, the applicator roller, and the backing or support roller. The coating is contained in a pool between the metering and applicator rollers and a coating dam. The metering roller picks up the coating material from the pool and transfers it to the applicator roller. The applicator roller then transfers the coating to a continuous sheet as it traverses between the backing and applicator rollers. The coated web passes through an oven similar to Figure 3-4 for fusion of the vinyl to the substrate.

Advantages of the coating process are that the capital costs are less than the calender equipment and it is economical for short runs of specialty items. Disadvantages are that the coating process requires higher priced raw materials and higher labor costs than the calender process.

Extrusion of a web is described in Figure 3-5. The PVC resins, plasticizers, and pigments are blended together and fed to an extruder. The extruder heats and then forces the homogeneous mass through a narrow slit the width of the web. This vinyl coating is nipped to a fabric by pressure rolls and then cooled and wound in a roll. Although no production figures are available probably less than ten percent of the total FVC&P products are extruded.[3]

It is estimated that 20 percent of the supported FVC&P webs are expanded. The expansion generally takes place as the final step in the web formation process. If the final product is to be an expanded type, the web is coated with a vinyl coating containing various chemicals which emit an inert gas when heated to 469°K (375°F). This gas foams the vinyl layer as it passes through the expansion oven and provides a product having a special body quality. The application of the coating and the heating of the web is presented in Figure 3-3. Any supported

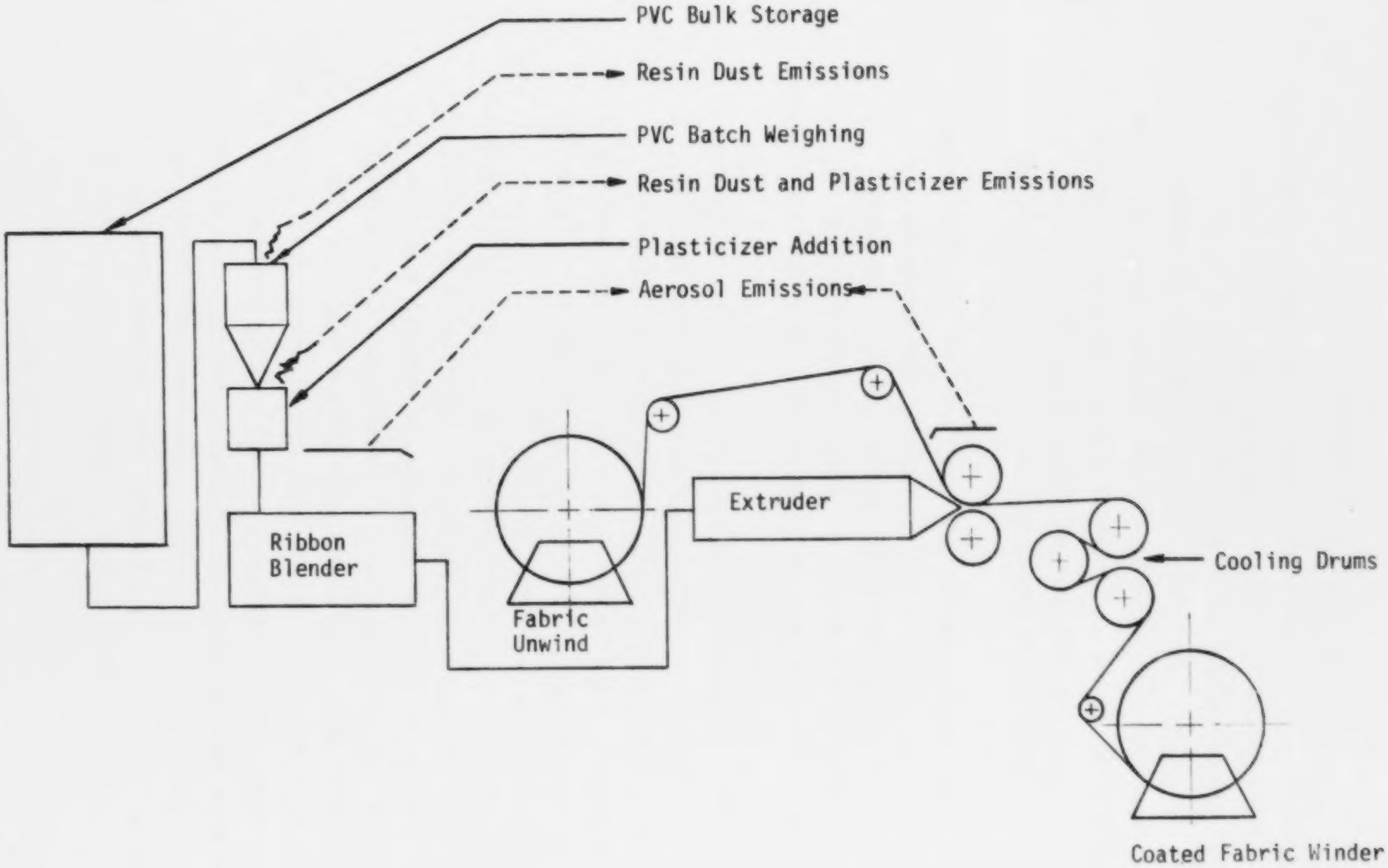

PVC Bulk Storage
Resin Dust Emissions
PVC Batch Weighing
Resin Dust and Plasticizer Emissions
Plasticizer Addition
Aerosol Emissions
Ribbon Blender
Fabric Unwind
Extruder
Cooling Drums
Coated Fabric Winder

Figure 3-5. EXTRUSION OF WEB

web may be expanded in a similar manner. Much of the expanded upholstery product used by the automotive industry has been replaced in recent years by a soft product which is not expanded and is more durable.[2]

3.2.4.2 Emissions. Aerosol emissions are evolved at several points in the preparation of the web. For the reasons stated below the emissions from the web formation processes are not considered further for NSPS. The sources are indicated as dotted lines in Figure 3-2, 3-3, and 3-5. These particulate emissions are presented in Table 3-2 and further described below.

Emissions from the calendering processes are high molecular weight organic compounds which condense into aerosols. They are primarily vaporized plasticizers from the heated material as it is blended, mixed, conveyed, calendered and cooled. Point source emissions are collected via ducts from the equipment and fugitive emissions are captured by hoods and suction pick up points.

Emissions from casting processes are aerosols similar to those described for the calendering process. Traces of solvent are also emitted from gelling and fusion ovens. Point source emissions are collected via ducts from the ovens. Some of the vapors and aerosols which evaporate are captured by hoods from the hot web as it leaves the ovens and are usually led back into the ovens.

Emissions from coating with knife or roller are similar to those described for the casting/coating processes. Emissions from extrusions processes are similar to those described for calendering processes.

Uncontrolled aerosol emissions from web formation in an average FVC&P plant are estimated to be 35 Mg (38 tons) per year. The VOC emissions are negligible since only a small amount of solvent is used for viscosity control in some of the plastisol coating processes.

Some of these aerosol emissions from web formation processes are controlled. Furthermore, it is unlikely that there will be many new installations of web preparation equipment over the next five years, for two reasons: there is a large amount of unused capacity available in

TABLE 3-2. ESTIMATE OF UNCONTROLLED WEB FORMATION EMISSIONS FOR AN AVERAGE FVC&P PLANT[d]

Sources	Aerosols		VOC	
	Mg per year	Tons per year	Mg per year	Tons per year
Web Formation				
a. Calendering[c]			Negligible	Negligible
Mixing[c]	0.45	0.5		
Banbury[c]	1.80	2.0		
Roll mills[c]	0.45	0.5		
Conveying[c]	0.27	0.3		
Calendar[b]	15.00	16.0		
Fugitives	in above	in above		
b. Extruding				
Mixer[c]	0.09	0.1	Negligible	Negligible
Extruder[c]	1.40	1.6		
c. Cast/coating			Negligible	Negligible
Preparation of coating	Negligible	Negligible		
Coating application	in below	in below		
Fusion ovens[b]	10.0	11		
Fugitives	in above	in above		
d. Expansion oven[c]	5.5	6	Negligible	Negligible
e. Laminating	Negligible	Negligible	Negligible	Negligible
Totals	35	38		

---

[a] Emissions for an average plant are based on estimated 1980 volumes of FVC&P products and assuming 100 plants. The plant would calendar 2.3 M kilogram (5 million pounds), cast/coat 0.8 M kilogram (1.8 million pounds) and extrude 0.3 M kilogram (0.6 million pounds) per year of web. Some of the web, 0.3 M kilogram (0.7 million pounds) per year would be laminated.

[b] Calculated from state and industry estimates of emission factors.

[c] Emission factors are estimated on basis of process and formulae information.

[d] Engineering estimate based on review of process, operating parameters.

calendering equipment[4] and this excess web preparation capacity can, in most cases, be utilized to meet the requirements of the growing product lines.

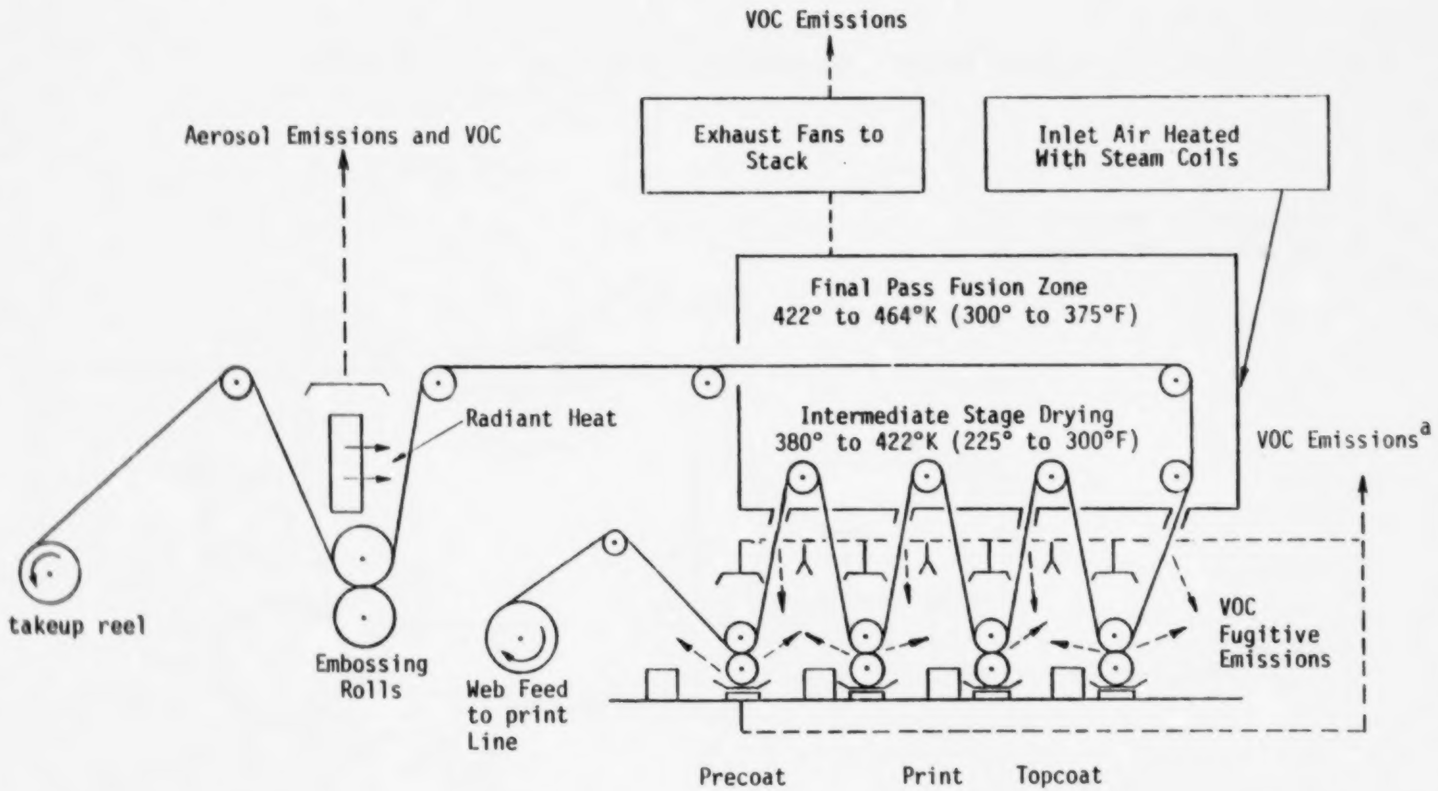
3.2.5 Finishing Operations

3.2.5.1 Processes. The major operations involved in FVC&P finishing operations are presented in Figure 3-6 and discussed below.

Most coatings and inks used in the finishing operations are solvent solutions of vinyl chloride/vinyl acetate copolymers and PVC resins. Smaller companies frequently buy ink concentrates. Larger companies compound inks in a variety of compositions and colors. Each manufacturer prepares inks and coatings in whatever tanks, and mixing equipment meet his individual needs. The compositions range from 70 percent solvent and 30 percent resin solids to 95 percent solvent and 5 percent solids, on a weight basis.[5] A typical ink or coating is 85 percent solvent and 15 percent solids. However, some manufacturers suggest 70 to 75 percent solvent and 25 to 30 percent solids inks can be used.[6]

A diagram of an individual rotogravure printing station is presented in Figure 3-7. The rotogravure principle is always used on these high speed continuous web lines. The gravure cylinder, on which the image surface has been etched, is about one-fourth submerged in a trough (the ink fountain) of ink or coating. Before a portion of the gravure cylinder contacts the paper, it picks up ink by rotation through the ink fountain. The ink used for rotogravure printing must instantly fill the cells or pores in the image zones of the cylinder's surface. Therefore, the ink must have a relatively low viscosity. The engraved cylinder is then scraped by a flexible "doctor blade" which removes the ink from the smooth non-image portion of the surface but leaves the ink in the cells.

There are many different arrangements of the printing stations in relation to each other and in relation to the oven(s)[5]. Most of the printing units are arranged in an in-line configuration. A few lines (less than 10 percent) use a U-type printer where the print heads are arranged around a central point.[5] (One manufacturer[6] suggests that 80 percent of the printing units in FVC&P industry are "U" shape printers.)


VOC Emissions
Aerosol Emissions and VOC
Exhaust Fans to Stack
Inlet Air Heated With Steam Coils
Final Pass Fusion Zone
422° to 464°K (300° to 375°F)
Radiant Heat
Intermediate Stage Drying
380° to 422°K (225° to 300°F)
VOC Emissions[a]
takeup reel
Embossing Rolls
Web Feed to print Line
VOC Fugitive Emissions
Precoat
Print
Topcoat

a) Some part of these emissions may be used as make up air to oven or otherwise circulated through oven and emitted as oven exhaust.

Figure 3-6. TYPICAL ROTOGRAVURE FINISHING LINE WITH EMBOSSER

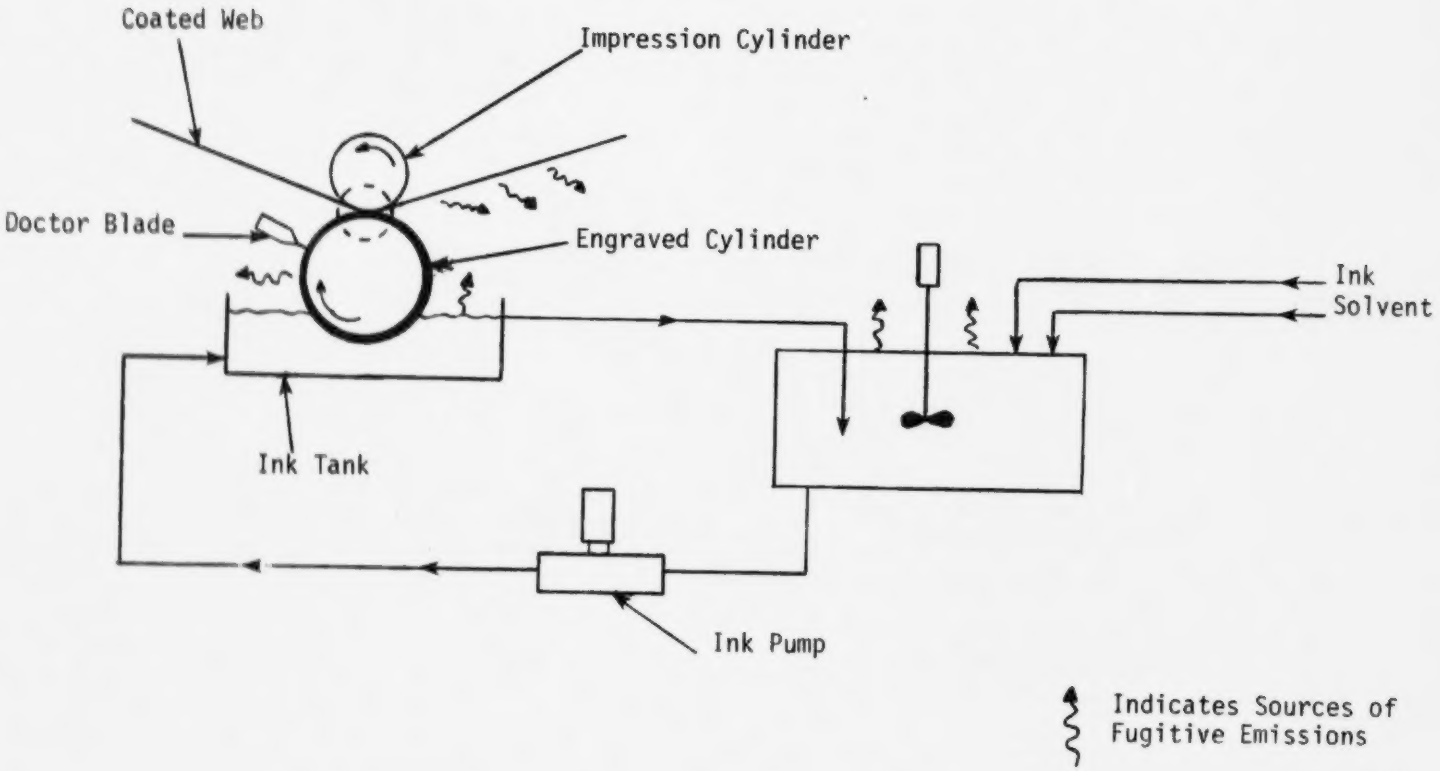

Coated Web
Impression Cylinder
Doctor Blade
Engraved Cylinder
Ink
Solvent
Ink Tank
Ink Pump
Indicates Sources of Fugitive Emissions

Figure 3-7. TWO-ROLL DIRECT ROTOGRAVURE COATING PROCESS

The in-line configuration is used in the newer plants to provide higher line speeds and higher recovery of solvent vapors.[1,2]

A typical finishing line as shown in Figure 3-6 includes the following steps:

Precoating. Only a few products are precoated. This step, which also utilizes rotogravure equipment provides an extra smooth surface for the printing step which follows.

Printing. Most FVC&P products are printed with one or more colors. Each print station prints a different pattern or color.

Wearcoat or Topcoating. Many supported fabrics, excluding residential wallcovering, are coated with a final topcoating to provide protection against scuffing and wear.

Fusion of Coating. Most FVC&P processes include a fusion step. Most solvent based coatings will form a continuous film upon air drying but plastisol and organisol coatings require a higher temperature, 422°K to 464°K (300°F to 375°F), which fuses the PVC and plasticizer into a continuous film.

The web is fed from a continuous roll through a series of rollers which precisely adjust its path through the rotogravure print stations. The rollers also help regulate the web tension and maintain constant speed. The web is pressed against the image surface of the gravure cylinder by a rubber roller, which serves as a backing. The point of contact between web and gravure cylinder is called the "nip" area. After the image has been transformed, the web travels through an enclosed oven where heated air evaporates the volatile solvent. The web then passes to the next printing unit.

In a typical controlled facility, the exhaust from the ovens is directed to a carbon adsorption system. This oven exhaust is vented to the atmosphere in an uncontrolled plant.

Several operating parameters of the finishing process are listed below.[1,2,7] Operating factors for the finishing line range from 40 to 60 percent due to time required for color changes, etc. Some manufacturers report operating factors as low as 25 to 30 percent due to color changes.[8] A typical factor for a new line would be 40 percent downtime or 3600 operating hours per year.

Line speed varies from 14 to 64 m (15 to 70 yards) per minute. A typical factor for a new line would be 55 m (60 yards) per minute. Product width ranges from 76 to 150 cm (30 to 60 inches). A typical width for a new line would be 76 cm (30 inches). Coating and ink application rate varies from 0.016 to 0.390 kg per square meter (0.03 to 0.72 pounds[8] per square yard) depending upon product requirements.

Coating and ink formulation varies from 5 to 30 (wt) percent solids or 95 to 70 (wt) percent solvent. These variations occur on the same line as a result of different product specifications. Some coating and ink formulations eliminate or minimize the solvent used in these coatings or inks.

The plastisols used to prepare the web, as described in Section 3.2.4, are usually 100 percent solids and contain no solvent except for small amounts used to adjust viscosity. These 100 percent solids coatings are viscous and not suitable for finishing operations.

Some manufacturers have attempted to substitute water for organic solvent. At least five major companies, along with several vendors, are seriously developing waterborne inks. The companies are:

- B.F. Goodrich[9]
- Columbus Coated Fabric[9]
- Chrysler Corporation[9]
- General Tire and Rubber (GTR)[10]
- Uniroyal[11]

It is thought that the first three companies are in preliminary developmental stages.

GTR is said to be producing seat belts for Volkswagon using a waterborne ink. This ink or coating has the following composition:[12]

	Weight %	Volume %
Non-volatiles	33.0	30.3
Water	48.4	50.3
Organics (VOC)	18.6	19.4

Density is 8.9 (lb/gal)

Uniroyal is making a major commitment in the development of waterborne inks. Currently, Uniroyal is investigating waterborne inks with the following composition:

0 - 15 wt. percent VOC
55 - 80 wt. percent water
20 - 30 wt. percent solids
Density varies from 9 - 11 lb/gal

Two major vendors of waterborne inks are Polyvinyl Chemicals and Sinclair and Valentine. Polyvinyl Chemicals, an ink manufacturing company, produces waterborne inks and resins for the FVC&P industry. A typical formulation is as follows:[13]

12.5 wt. percent VOC
34 wt. percent solids
53.5 wt. percent water

Sinclair and Valentine is probably the number one or two company in the ink supplying business. They report that the solvent concentrations in all their waterborne inks are below the CTG limit for the fabric coating industry.[9] However, these formulations have not been accepted by the FVC&P industry. They are difficult to dry[6] and there have been difficulties in obtaining the pigments and resins required for high quality products.

At present, organic solvents are used in most FVC&P finishing operations. Oven air flow ranges from 60 dry standard cubic meters per minute (2000 scfm) to 450 dry standard cubic meters per minute (16,000 scfm) per line depending upon desired drying rate and web and coating drying characteristics, line widths, line speed, and number of print heads.

The solvent content in oven air varies from 0 to 50 percent of the lower explosive limit (LEL). The LEL is the lowest vapor concentration in air, expressed as volume percent, at which the mixture could support a flame or explosion at temperatures below 121°C (250°F). Insurance safety regulations require normal operation at less than about 25 percent of the LEL. Operation up to 50 to 60 percent of the LEL is permitted when continuous vapor monitoring systems are employed to control the vapor concentration in the air.

Major raw materials for pringing vinyl are usually PVC resins or vinyl chloride/vinyl acetate copolymer, plasticizers, pigments and solvents. The solvents are primarily ketones, however, tetrahydrafuran, toluene, xylene, and many other solvents are also used in small quantities. Urethanes and acrylic systems are sometimes used on the same equipment. Many of these operating parameters are interrelated. For example, changes in web width, line speed, ink or coatings coverage, and solvent type influence the oven exhaust flow rate and solvent concentration. For example, a finishing line operating with a narrow web on a wide cylinder will produce a dilute oven exhaust stream. The width of the oven must be large enough to accomodate the widest desired web. Only a portion of the makeup air will be flowing over the printed product. The decreased solvent loading will result in a lower concentration of solvent in the solvent laden air (SLA) stream. Most ovens are capable of internal exhaust recirculation and air flow can be adjusted to provide adequate fresh air makeup, without excessive oven exhaust dilution. Excessive oven exhaust dilution requires a larger SLA collection and control system. Thus the emission control systems become more expensive as the SLA flow increases.

3.2.5.1 Emissions. There are VOC and traces of aerosol emissions at several points in the finishing or printing operations. The majority of the solvent used on a flexible vinyl finishing line is driven off in the drying operation after the inks have been applied to the vinyl web. These vapors are usually contained in an oven and the oven gases are drawn through a fan and ducted away from the work area. Solvent vapors not captured by the drying ovens may be collected by the vapor capture system. The vapors that are not captured and which escape to the atmosphere are called fugitive emissions. These emissions are indicated on Figure 3-6 and 3-7 and are further described below.

Uncontrolled emissions for an average size FVC&P plant are presented in Table 3-3. Aerosol emissions from the finishing operation of the average plant are estimated to be less than 0.9 Mg (1 ton) per year and therefore these emissions will not be considered further.

TABLE 3.3 ESTIMATE OF UNCONTROLLED FINISHING AND EMBOSSING EMISSIONS FOR AN AVERAGE PLANT[a]

Sources	Aerosols		VOC	
	Mg per year	Tons per year	Mg per year	Tons per year
Preparation of coating[c]	Negligible	Negligible	23	25
Cleanup[c]	Negligible	Negligible	29	32
Printing				
Ovens[b]	0.9	1	490	540
Fugitives[d]	in above	in above	130	140
Printing subtotal			620	680
Embosser[b]	7	8	9	10
TOTALS	8	9	680	750

[a] Emissions for an average plant are based on estimated 1980 volumes of FVC&P products and assuming 100 plants. The plant would finish 6 million square meters (7 million square yards) of supported fabric and 0.9 M kilogram (2 million pounds) of unsupported sheet. After finishing, the plant would emboss 5 million square meters (6 million square yards) of supported fabric products. Very little information is available as to how much unsupported sheet is printed. However, assuming that the printed unsupported product volume is approximately 40 percent of the supported product volume, then the VOC printing emissions of 620 Mg (680 tons) per year would be 0.075 kilogram per square meter (0.139 lbs per square yard).

[b] Calculated from state and industry estimates of emission factors. One manufacturer[8] states oven emissions cannot be more than 66 percent of total, or 449 Mg per year. If the printing subtotal is correct, this would mean that 72 percent of the VOC was captured by the oven and 28 percent was fugitive.

[c] Emission factors are estimated on basis of process and formulae information.

[d] There is very little data as to the quantity of fugitives emitted during the printing operation. This is an estimate based on observations during field trips and engineering judgement.

The VOC emissions from an average printing operation are estimated to be 620 Mg (680 tons) per year. The actual amount of VOC emissions in any given operation will depend upon the quantity of solvents used in the application of the inks in the finishing operations. However, all of the solvent used to dissolve the resins ultimately enters the environment and most of it is emitted during the drying of the inks.[14] There is very little information on what portion of this solvent is in the oven gases and what portion is emitted as fugitives. Fugitive emissions from a flexible vinyl print line are defined as all VOC which are emitted from: the print line ink fountains, the rotogravure print heads, the wet web prior to its entering the drying ovens, and any other VOC emissions escaping from the print line. In Table 3-3 it was assumed that 21 percent of the solvent entering the print station was emitted as fugitive vapors and 79 percent of the solvent was removed in the oven. As indicated in Table 3-3, one manufacturer[8] states that the no more than 72 percent of the printline emissions can be captured in the oven. The finished product is reported by one manufacturer to have negligible quantities of VOC.[15] Another manufacturer[16] states that there may be from one to nine percent solvent in the product as it leaves the print line.

As estimated in Table 3-3, in an average plant, 23 Mg (25 tons) per year of VOC are emitted during preparation of the coating. The coating or ink is prepared in a variety of ways as discussed in the preceding section. These operations are generally conducted in equipment especially designed to control the emissions of solvent vapor and the work areas are well ventilated to control the VOC emissions in order to comply with OSHA standards and to reduce the explosion hazard. In new plants where carbon adsorbers have been installed these VOC emissions are recovered. The quantity of these VOC emissions is small and the equipment and arrangement for each plant is different, therefore these VOC emissions are not considered further for NSPS.

In addition it is estimated that 29 Mg (32 tons) per year of VOC are emitted during clean up of the print roll and the print station. Generally these VOC emissions are captured by whatever hoods and fugitive pick up ducts are used to control the fugitives emitted during the coating process.

Most of the emissions occur when the wet web is heated to remove the solvent and fuse the resin into a continuous film. These solvent vapors are usually contained in an oven and the oven gases are drawn through a fan and ducted away from the work area. There is no data to characterize these oven emissions. They make up 70 to 90 percent of the solvent entering the print stations depending upon the volatility of the solvent, coating thickness, exposure time of the wet web to the atmosphere, residence time in the oven and other process and equipment parameters such as air flows and temperatures.

The balance of the solvent entering the print station escapes as fugitives. There are no data available to quantify these emissions. The estimates presented in Table 3-3 are based on conversations with plant personnel during nine plant trips.

3.2.6 Embossing

3.2.6.1 Processes. Most FVC&P products are embossed to improve appearance and wearability. Process details are indicated in Figure 3-7. The embossing press consists of two basic components: a rubber sleeve support roller and a embossing cylinder. The image pattern is formed in the surface of the embossing cylinder by mechanical or chemical means. The vinyl coated web is heated and continuously drawn between the embossing and support rollers. As it passes through the cooled rollers, the image or pattern is set in the hot web surface.

Most FVC&P products are embossed as part of the finishing operation. The embosser is often installed at the end of the print line as shown in Figure 3-7. However, many manufacturers transfer the printed sheet to an embosser located elsewhere in the plant.

Other exceptions are calendered and laminated products. As previously described most calendered products are embossed with a matte or special finish as they exit the calender. Also, as previously described some products are manufactured by laminating an unsupported sheet to a fabric substrate as a separate operation, and embossing is generally part of that laminating step.

3.2.6.2 Emissions. There are aerosol and varying amounts of VOC emissions, depending on the printing process, from the finishing embossing operation. These are indicated in Figure 3-6. The aerosols are high molecular weight organic compounds which condense as they exit with the stack gases. They are primarily vaporized plasticizers from the heated coating and web. Aerosol emissions from the embossing operation of an average plant, would be 7 Mg (8 tons) per year. These aerosol emissions are highly visible. Hoods are installed over most embossers and state opacity regulations generally require new installations to capture and control these emissions. These small quantities of aerosols are not considered in the FVC&P NSPS.

3.3 BASELINE EMISSIONS

Existing state regulations applicable to the FVC&P industry are presented in Section 3.3.1 and the logic and rationale leading to the selection of the baseline emission level are presented in Section 3.3.2. The baseline emission level is the level of emission control that would be achieved by the affected industry in the absence of an NSPS. The baseline emission level is established to facilitate comparison of the economic, energy, and environmental impacts of the regulatory alternatives.

3.3.1 State and Local Emission Regulations

Table 3-4 presents a summary of the current state regulations for volatile organic compound emissions.[17] Twenty states, the District of Columbia, and Puerto Rico have some form of regulation to limit the emission of VOC. All but one of the remaining states have an ambient air quality standard but no emission limits.

Of the existing state regulations, the most restrictive standard calls for a maximum of 6.8 kilograms per day (15 pounds per day) or 1.4 kilograms per hour (3 pounds per hour) for "oven emissions." Oven emissions are defined as organic materials emitted from coating operations wherein the coating is baked, heat-cured, heat-polymerized, or comes in contact with a flame. If these ceiling values cannot be met, control equipment must be provided to reduce the oven emissions by at least 85 percent.

TABLE 3-4. EXISTING STATE REGULATIONS ON EMISSIONS OF VOLATILE ORGANIC COMPOUNDS APPLICABLE TO THE VINYL COATING AND PRINTING INDUSTRY

State	Emission limits					Notes
	kg/day	(lb/day)	kg/hr	(lb/hr)	% Reduction	
Alabama	---	--	---	-	--	i
Alaska	---	--	---	-	--	b
Arizona	6.8	15	---	-	--	a, c
Arkansas	---	--	---	-	--	b
California	6.8	15	1.4	3	85	a, d, e, g
Colorado	6.8	15	1.4	3	85	a
Connecticut	---	--	---	-	--	f
Delaware	---	--	---	-	--	i
Florida	---	--	---	-	--	i
Georgia	---	--	---	-	--	j
Hawaii	---	--	---	-	--	b
Idaho	---	--	---	-	--	b
Illinois	---	--	---	-	--	j
Indiana	6.8	15	1.4	3	85	e
Iowa	---	--	---	-	--	h
Kansas	---	--	---	-	--	i
Kentucky	---	--	---	-	--	i
Louisiana	---	--	---	-	--	i
Maine	---	--	---	-	--	h
Maryland	---	--	---	-	--	i
Massachusetts	6.8	15	1.4	3	85	j
Michigan	---	--	---	-	--	k
Minnesota	---	--	---	-	--	b
Mississippi	---	--	---	-	--	b
Missouri	---	--	---	-	--	j
Montana	---	--	---	-	--	b

TABLE 3-4. (continued). EXISTING STATE REGULATIONS ON EMISSIONS OF VOLATILE ORGANIC COMPOUNDS APPLICABLE TO THE VINYL COATING AND PRINTING INDUSTRY

State	Emission limits					Notes
	kg/day	(lb/day)	kg/hr	(lb/hr)	% Reduction	
Nebraska	---	--	---	-	--	b
Nevada	---	--	---	-	--	b
New Hampshire	---	--	---	-	--	i
New Jersey	---	--	---	-	--	i
New Mexico	---	--	---	-	--	b
New York	---	--	---	-	--	i
North Carolina	---	--	---	-	--	i
North Dakota	---	--	---	-	--	b
Ohio	---	--	---	-	--	i
Oklahoma .	6.8	15	1.4	3	85	a
Oregon	---	--	---	-	--	j
Pennsylvania	---	--	---	-	--	i
Rhode Island	---	--	---	-	--	j
South Carolina	---	--	---	-	--	i
South Dakota	---	--	---	-	--	b
Tennessee	---	--	---	-	--	b
Texas	---	--	---	-	--	i
Utah	---	--	---	-	--	b
Vermont	---	--	---	-	--	No regulation
Virginia	---	--	---	-		j
Washington	---	--	---	-	--	b
West Virginia	---	--	---	-	--	b
Wisconsin	---	--	---	-	--	i
Wyoming	---	--	---	-	--	b
District of Columbia	6.8	15	1.4	3	85	a, e
Puerto Rico	6.8	15	1.4	3	--	f, o

TABLE 3-4. (continued). EXISTING STATE REGULATIONS ON EMISSIONS OF VOLATILE ORGANIC COMPOUNDS APPLICABLE TO THE VINYL COATING AND PRINTING INDUSTRY

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a) Applies to oven emissions (organic compounds which have been exposed to a flame or have been heat cured, heat polymerized, or baked).

b) Ambient air standard only.

c) Maricopa County only. Rest of the state calls for "no unreasonable escape of solvents and use of control equipment where needed."

d) Applies to County of Los Angeles and San Francisco Bay Area APCD. County by county regulations, most following this pattern.

e) Applies to photochemically reactive solvents, as defined in Rule 66.

f) Total emissions.

g) Applies to AQCR 7 only.

h) Unless equipped with acceptable control.

i) VOC emissions should not exceed 0.45 kilograms per liter (3.8 pounds per gallon) of coating, excluding water, delivered to the coating applicator.

j) VOC emissions should not exceed 0.35 kilograms per liter (2.9 pounds per gallon) of coating, excluding water.

k) VOC emissions should not exceed 0.54 kilograms per liter (4.5 pounds per gallon), excluding water.

The current state regulations do not cover the fugitive VOC losses from vinyl coating applicators/processing, printing/topcoating presses, solvent cleaning and handling, and ink preparation. These losses can account for up to 30 percent of a vinyl coating plant's total solvent emissions.[7]

The states that are non-attainment areas for photochemical oxidants are currently preparing and submitting State Implementation Plans (SIP) to the U.S. EPA for approval. As required in the Clean Air Act, the U.S. EPA has published a series of Control Techniques Guideline (CTG) documents containing information and recommended emission limits for particular industries. A summary of the CTG document for coating of fabric and vinyl is presented in Table 3-5.[18]

As a result of the fabric and vinyl coating CTG, some states' SIP are calling for 90 percent capture of the solvent in the ink and coating formulations that enter the coating and printing equipment.[19] These same SIP also require 90 percent control of the captured emissions which results in an 81 percent overall reduction of VOC emissions from coating and printing processes. This reduction is approximately equivalent (based on 15 percent solids by volume) to the CTG emission limit of 0.45 kg per liter (3.8 lb/gal) of coating minus water.

Some states have not used the fabric and vinyl coating CTG to develop their SIP, but instead have used the CTG document developed for rotogravure printing because a [illegible]gravure technique is used to print flexible vinyl. The rotogravure CTG document covers publication and packaging rotogravure and flexographic printing. A summary of this CTG document is presented in Table 3-6.[20]

The flexible vinyl printing industry has been classified under the packaging rotogravure category. This category requires a 65 percent overall VOC reduction wherever packaging rotogravure printing is used. The rotogravure CTG also allows the use of waterborne inks to meet the specified level of control. If waterborne inks are used, the volatile fraction of the ink must contain 25 percent or less by volume organic solvent and 75 percent or more water. High solids inks must contain 60 percent or more by volume nonvolatile material.[11]

TABLE 3-5. SUMMARY OF CTG DOCUMENT FOR COATING OF FABRIC AND VINYL[18]

Affected facilities	Fabric and vinyl surface coating lines including the application areas and the drying ovens. Fabric coating includes all types of coatings applied to fabric. Vinyl coating refers to any printing, decorative, or protective topcoat applied over vinyl coated fabric or vinyl sheets.
Number of affected facilities	Estimated to be 130 facilities nationwide.
VOC emissions nationwide	Estimated annual emission from fabric coating operations are 100,000 Mg/yr (110,000 ton/yr. [15] The vinyl segment of the fabric industry emits about 36,000 Mg/yr (40,000 tons/yr). VOC from fabric coating represents about 0.4 percent of the estimated VOC emissions nationwide.
VOC emission range per facility	Average annual VOC emissions are estimated to be 850 Mg (940 ton).
100 ton/yr source size	Any but the smallest fabric coating facilities should exceed emissions of 100 ton/yr of VOC.
CTG emission limit	The recommended VOC emission limits are: a. Fabric coating 0.35 kg per liter of coating minus water (2.9 lb/gal). b. Vinyl coating 0.45 kg per liter of coating minus water (3.8 lb/gal).
VOC reduction per facility	The actual percent reduction will vary depending on the solvent content of the existing coatings and the control method selected. Implementation of the recommended control methods can reduce VOC emissions by 80 to 100 percent.
Costs	BASIS: 15,000 scfm facility using incineration with primary heat recovery or adsorption with recovered solvent credited at fuel value. Capital cost: $150,000 - $320,000 Annualized cost: $ 60,000 - $ 75,000 Cost effectiveness: $34 - $39 per ton VOC

TABLE 3-6. SUMMARY OF CTG DOCUMENT FOR GRAPHIC ARTS - ROTOGRAVURE AND FLEXOGRAPHY

Affected facilities (p. 1-1)*	Flexographic and rotogravure processes applied to publication and packaging printing.
Number of affected facilities (p. 2-5)*	a. Publication printing is done in large printing plants, numbering less than 50 in total. b. There are approximately 13 to 14 thousand gravure printing units and 30 thousand flexographic printing units.
VOC emissions nationwide (p. 2-8)*	a. Gravure 100,000 Mg/yr 1976 (110,000 tons/yr) b. Flexography 30,000 Mg/yr 1976 (33,000 tons/yr) This represents about[11] 0.8 percent of stationary source estimated emissions.
VOC emission range per facility (calculated)	a. Gravure 7.4 Mg/pringin unit per year (8.2 tons/unit) b. Flexography 1 Mg/pringing unit per year (1.1 tons/printing unit per year)
100 tons/yr source size	A plant will be a potential 100 tons/yr VOC source if it uses 110-180 Mg (120-200 tons) of ink per year, where the solvent concentration is 50-85 percent.
CTG emission limit (pp. 1-2, 1-3)*	Use of water-borne or high solids inks meeting certain composition criteria or the use of capture and control equipment which provides: a. 75 percent overall VOC reduction where a publication rotogravure process is employed; b. 65 percent overall VOC reduction where a packaging rotogravure process is employed; or, c. 60 percent overall VOC reduction where a flexographic printing process is employed.

*The source of the summary information is the indicated page number in "Control of Volatile Organic Emissions from Existing Stationary Sources, Volume VIII: Graphic Arts - Rotogravure and Flexography," EPA-450/2-78-033.

3.3.2 Selection of the Baseline Emission Level

The baseline emission level should represent the emission reduction which has been demonstrated to be achievable by the majority of existing flexible vinyl printing facilities. Contacts with existing controlled flexible vinyl facilities and state regulatory agencies indicate that the 65 percent control level of the packaging rotogravure printing CTG is being applied to existing facilities in several states. Therefore, the 65 percent overall control level is selected as the baseline for this study.

3.4 REFERENCES

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8. Letter from Niles, R.W., Uniroyal Inc. to Laube, A.H., Radian Corporation. December 4, 1980.

9. Telecon. Krohn, N.E., Radian Corporation, with Weimer, R., Sinclair & Valentine. February 2, 1981. Conversation about waterborne inks.

10. Meeting Notes. Laube, A.H., Radian Corporation, with Laundrie, R., General Tire and Rubber Corporation. February 5, 1981. Conversation about waterborne inks.

11. Letter from Niles, W. Uniroyal Inc., to Crumpler, D., EPA. February 2, 1981.

12. Letter from Laundrie, R.W., The General Tire & Rubber Company, to Krohn, N.E., Radian Corporation. February 16, 1981.

13. Telecon. Krohn, N.E., Radian Corporation, with Fitzwater, J., Polyvinyl Chemicals. January 27, 1981. Conversation about waterborne inks.

14. Trip report. Laube, A.H., Radian Corporation, to file. October 10, 1979. 4 p. Report of September 28, 1979 visit to Uniroyal in Mishawaka, Indiana.

15. Trip report. Laube, A.H. and D.T. Smith, Radian Corporation, to file. January 27, 1980. 6 p. Report of December 12, 1979 visit to Stauffer Chemical Company in Anderson, South Carolina.

16. Letter from Ilg, W.G., Columbus Coated Fabrics, to Laube, A.H., Radian Corporation. December 5, 1980.

17. Status summary of State Group I VOC RACT Regulations as of March 10, 1980. GCA Corporation. Bedford, Massachusetts. May 1980.

18. Peterson, P.R. and R.R. Sakaida. (Pacific Environmental Services, Inc.) Summary of Group 1 Control Technique Guideline Documents for Control of Volatile Organic Emissions from Existing Stationary Sources. (Prepared for U.S. Environmental Protection Agency.) Research Triangle Park, N.C. Publication No. EPA-450/3-78-120. December 1978. p. 2-8.

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4. EMISSION CONTROL TECHNIQUES

The flexible vinyl coating and printing (FVC&P) industry has significant emissions of volatile organic compounds (VOC). These emissions occur throughout the FVC&P plant wherever solvents are handled. All of these VOC emissions have been characterized in Chapter 3. Only the VOC emissions associated with the FVC&P finishing processes will be discussed here. VOC emissions from storage, formulation activities, and cleanup are not included in this discussion. VOC emissions from solvent storage tanks are being examined in a separate NSPS background document. Formulation VOC emissions are already controlled to low levels due to safety reasons. VOC cleanup emissions are generally low concentration, low volume sources which are very difficult to capture and control. The combination of these three emissions sources is less than ten percent of the total amount of VOC emitted from a typical FVC&P plant.

In the finishing operation VOC emissions result from the evaporative loss of organic solvent as:

- process emissions (exhaust from drying ovens) and
- fugitive emissions (unintentional solvent evaporation from the coating operation itself).

The printing and topcoating finishing operations are the principle sources of VOC emissions in the FVC&P industry. This chapter will review the technology available for the control of VOC emissions.

There are five basic control technologies used to reduce VOC emissions. Those technologies are:

- carbon adsorption
- incineration
- wet scrubbing

- condensation, and
- process modification.

Of these five technologies, only carbon adsorption, incineration, and wet scrubbing will be discussed in detail in Section 4.1. Although not used in the FVC&P industry condensation will be described briefly because it is an innovative technology that has been successfully used in the fabric coating industry and other related surface coating industries to control VOC emissions. Process modifications, including changeovers to low-VOC content (waterborne) inks, were covered in Chapter 3.

Carbon adsorption and incineration would be considered equivalent in overall control effectiveness for reducing VOC emissions from vinyl coating and printing facilities. The selection of either of these control methods is dependent upon the specific application. When carbon adsorption can be applied without unusual operating problems, it usually holds an economic advantage because of the value of the recovered solvent.

There are some applications, however, where the cost of auxiliary equipment necessary to recover and purify solvent would be high enough that incineration would be given careful consideration. The following is a list of general factors which would favor incineration (the absence or converse of these factors would therefore favor carbon adsorption):

- mixture of several solvents (which would require distillation and reformulation to reuse),
- coatings that give off relatively high levels of entrained particulates (which might foul and deactivate a carbon bed),
- water soluble solvents (which would require water treatment or some form of noncondensable regenerant), and
- solvents whose market value approaches their fuel value.

While both carbon adsorption and incineration are equally effective as emission controls, they are not as effective as process modifications. Modifications such as waterborne inks hold a distinct advantage because of the negligible amount or total absence of solvent. This absence or negligible amount of solvent negates the difficult to control fugitive emission problem. Wherever applicable, alternate coating techniques hold a strong advantage in environmental, energy, and economic factors. These alternate coating techniques have not, however, been sufficiently developed to replace solvent-based coating in most of the FVC&P industry applications. The use of solvent systems with control devices is required throughout the FVC&P industry.

4.1 VOLATILE ORGANIC COMPOUND CONTROL

4.1.1 Carbon Adsorption

Carbon adsorption is a method of reducing VOC emissions by adsorption of the organic to the surface of activated carbon. The VOC are subsequently desorbed from the bed and recovered. Carbon adsorption is a mature technology that has been applied to the control of VOC emissions from a wide range of industrial processes, including vinyl coating and printing. Its theory and principles have been extensively covered in the literature. A very brief discussion of the operation of carbon adsorption units will be presented here, with emphasis placed on the specific applications in the FVC&P industry.

4.1.1.1 Operating Principles. Although there are several types of continuous carbon adsorption units, most existing facilities use multiple fixed bed adsorbers which are cycled in and out of service. Essentially this cycling results in each adsorber operating in a batch mode. These modes are characterized by an adsorption cycle and a regeneration cycle. The operating discussion will be divided into these cycles (see Figures 4-1 and 4-2).

In the adsorption cycle, the gas containing VOC is routed to an adsorber containing freshly regenerated carbon. The VOC is quickly adsorbed onto the surface of the carbon, and the gas exits with a very low VOC concentration. As the capacity of the bed to hold VOC is used up, the exit VOC concentration begins to rise. This is called the breakthrough point, and it signals the need to switch the adsorber to the regeneration cycle. Following the switch to regeneration, another adsorber is moved into the adsorption cycle.

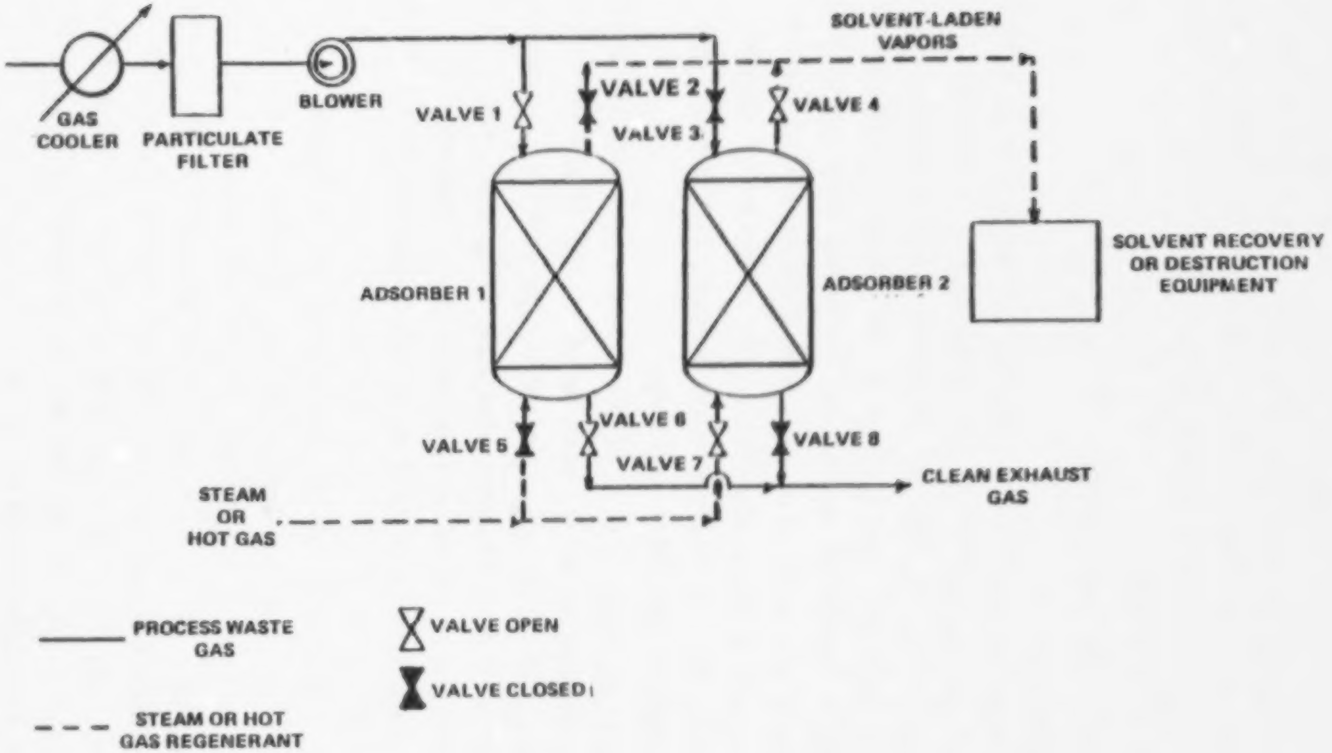

SOLVENT-LADEN VAPORS
GAS COOLER
PARTICULATE FILTER
BLOWER
VALVE 1
VALVE 2
VALVE 3
VALVE 4
ADSORBER 1
ADSORBER 2
SOLVENT RECOVERY OR DESTRUCTION EQUIPMENT
VALVE 5
VALVE 6
VALVE 7
VALVE 8
CLEAN EXHAUST GAS
STEAM OR HOT GAS
PROCESS WASTE GAS
STEAM OR HOT GAS REGENERANT
VALVE OPEN
VALVE CLOSED

Figure 4-1. Schematic of two-bed adsorber unit: adsorber 1 adsorbing, adsorber 2 regenerating.

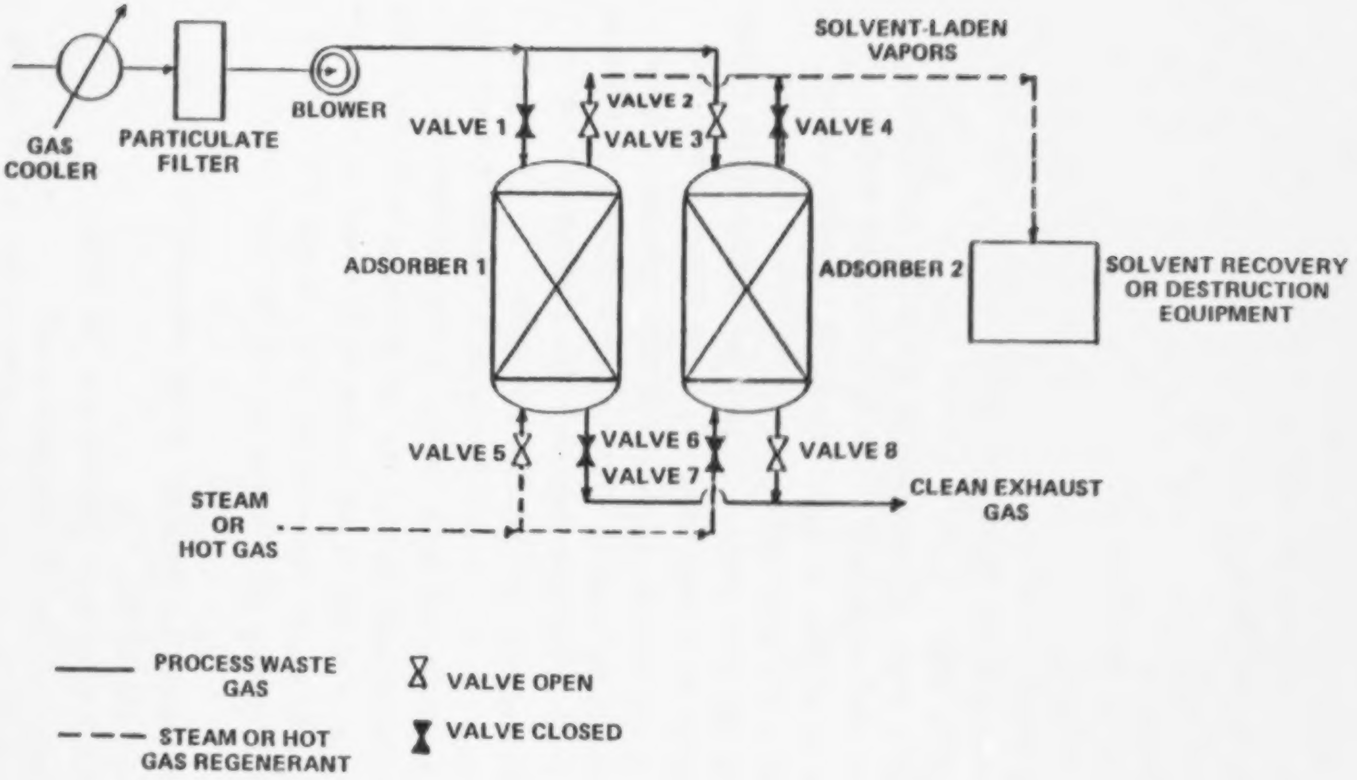

GAS COOLER
PARTICULATE FILTER
BLOWER
VALVE 1
VALVE 2
VALVE 3
VALVE 4
SOLVENT-LADEN VAPORS
ADSORBER 1
ADSORBER 2
SOLVENT RECOVERY OR DESTRUCTION EQUIPMENT
VALVE 5
VALVE 6
VALVE 7
VALVE 8
STEAM OR HOT GAS
CLEAN EXHAUST GAS
PROCESS WASTE GAS
STEAM OR HOT GAS REGENERANT
VALVE OPEN
VALVE CLOSED

Figure 4-2. Schematic of two-bed adsorber unit: adsorber 1 regenerating, adsorber 2 adsorbing.

The important parameters during the adsorption mode include:

- degree of regeneration (or working capacity of carbon),
- VOC inlet concentration (% LEL),
- gas flow rate,
- cycle time,
- temperature of the inlet gas,
- type of solvent,
- type and amount of carbon,
- superficial velocity in the bed, and
- bed pressure drop.

The first six factors affect the variance of day to day operations, while the latter factors are generally set by the initial design.

There are two basic types of bed regeneration, thermal and low pressure. Both types are based on increasing the volatility of the adsorbed organic to the point where it leaves the surface of the carbon. Low pressure regeneration is best suited to units with very high VOC loadings, and it is not used to any extent in this industry. Thermal regeneration may be accomplished by either steam or other hot gas, with steam being used in all FVC&P applications. Hot air regeneration can be attractive when dealing with water soluble solvents.

The regeneration cycle is also illustrated in Figures 4-1 and 4-2. Steam is introduced to the bed which is loaded with adsorbed VOC. This results in desorption by both heating the bed and steam stripping. The combined water and organic vapors are condensed in a heat exchanger and routed to a storage tank (see Figure 4-3). From storage the solvent/ water solution is sent to a distillation column for final solvent reclamation.

The important operating variables during regeneration include:

- length of the cycle,
- pressure and degree of superheat of the steam,
- condenser water outlet temperature, and
- use of cooldown, drying, or expansion cycles before returning the bed to the adsorption mode.

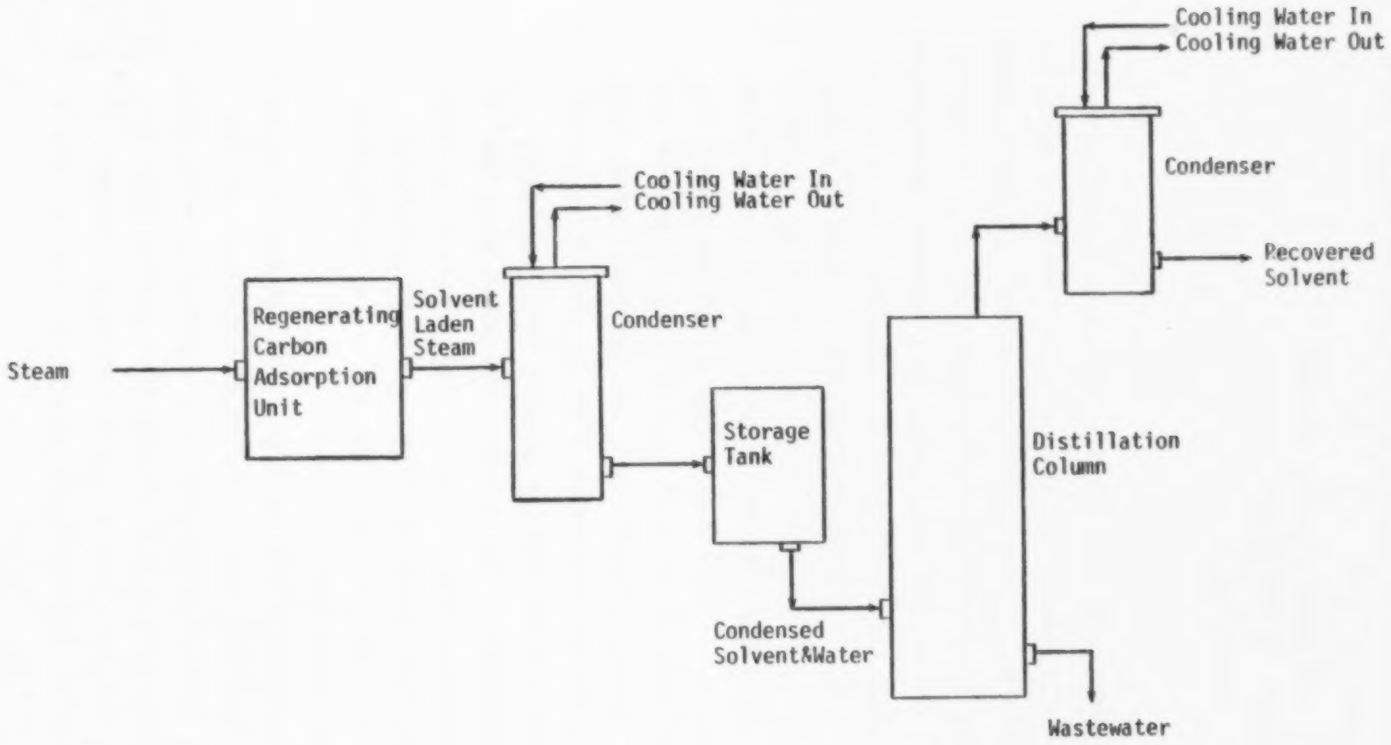

Cooling Water In
Cooling Water Out
Condenser
Recovered Solvent
Cooling Water In
Cooling Water Out
Solvent Laden Steam
Condenser
Steam
Regenerating Carbon Adsorption Unit
Storage Tank
Distillation Column
Condensed Solvent&Water
Wastewater

Figure 4-3. Schematic of Solvent Recovery by Condensation and Distillation

4.1.1.2 Operating Problems. There are several areas of operating problems with carbon adsorption units in the vinyl coating and printing industry. Among these are:

- nonregenerable compounds fouling the bed,
- recovered solvent contamination,
- solvent/water separation,
- bedfires, and
- corrosion.

Many operating problems are associated with high boiling compounds fouling the carbon bed. Polyvinyl chloride and other resins present in coatings tend to be picked up by the collection system.[1] These compounds can plug and foul the carbon bed of a carbon adsorption unit. Plugging would decrease bed efficiency, increase steam requirements, and increase the unit's operating costs. Also, it has been theorized that iron (in the form of mild steel) used in equipment construction acts as a catalyst to form high boiling compounds in the carbon bed. One manufacturer tested this theory in laboratory glassware, and produced more than 20 identifiable heavy organics.[2] These heavy organic compounds foul the carbon beds rapidly, and because of their high boiling nature are not easily desorbed. This increases steam usage and shortens carbon life.

There are several problems associated with the use of recovered solvents. Multicomponent systems usually require distillation to separate the solvent components. The solvent components must then be reformulated to meet specifications. Even in single solvent systems, the recovered solvent may not always be suitable for reuse without further treatment. Trace materials may alter the solvent properties enough that it no longer meets specifications.

Because of the solubility of MEK in water, the process of solvent/water separation is an important one in the FVC&P industry. In the plants surveyed in this study, two methods were reportedly being used for this separation. They were: distillation in a packed tower or plate column and extraction in a liquid-liquid extraction column.[3,4,5] In plants using distillation the recovered solvent is treated with a desiccant such as calcium chloride to dehydrate it. Adjustment of pH is also necessary to prevent corrosion of the distillation unit. The pH of the initial, untreated solvent ranges around 4 to 4.5.[5] Neutral pH condititon are desired for these systems. The importance of the pH adjustment should be stressed. A solvent mixture that is too acidic will result in severe corrosion. If the mixture is alkaline, polymerization of the MEK results in formation of solid matter which causes quality problems and reduces yield.[4]

For plants using liquid-liquid extraction columns, pH adjustment is performed before any water separation processes begin. Sodium hydroxide is again used as the treatment chemical. Following pH treatment the MEK-water solution is sent to an extraction column. The MEK is separated from the water by solvent extraction with toluene. Toluene is injected at the bottom of the column and contacted with the MEK-water solution. An MEK-toluene mixture is removed from the top of the column and water is drawn off at the bottom. The MEK-toluene mixture is sent to a conventional distillation column for the separation of the two solvents. The distillation process recovers MEK and allows toluene to be recycled to the extraction column.

Most recovered solvent in this industry is reused in the coating process or used as wash solvent. There are two options for disposing of recovered solvent that cannot be reused. The first is to sell this material back to the solvent supplier or an independent firm that specializes in reclaiming contaminated solvents. Payment for the spent solvent usually takes the form of a credit against fresh solvent purchases, and it is typically only about 30 percent of the virgin solvent price.[6] Another possibility is the use of recovered solvent as a fuel in the boiler or the drying oven burners. Many of these devices are currently gas fired, however, and would require burner modifications before being able to burn the solvent. There is little economic incentive to burn solvent since most solvents cost a great deal more than fuel oil. Carbon adsorption is generally economically attractive only if the recovered solvent can be reused directly.

Corrosion is often a problem in carbon adsorption systems. Most of the solvents used in the vinyl coating and printing industry are not intrinsically corrosive, but corrosive compounds may be formed in the bed. The process is similar to that previously described in the formation of high boiling compounds. The predominantly used ketone solvents in this industry can break down in the carbon bed to form various corrosive acids and peroxides. Corrosion resulting from such byproducts has caused one major manufacturer to replace much of the mechanical internals and supports of a carbon adsorption system after only two years of operation. This manufacturer reported that 0.2 percent of the MEK solvent passing through the adsorption system broke down to diacetyl products.[12] Also, processes which use direct-fired heaters may have problems with adsorbed carbon dioxide. On steam regeneration, the CO_2 combines with water to form corrosive carbonic acid.

Another potential problem is the occurrence of carbon bed fires. These apparently result from spontaneous ignition of solvent on the carbon surface. Since adsorption is an exothermic process, it is possible that heat liberated in a dead spot (with no air flow to cool it) could rise to the auto-ignition temperature. The occurrence of bed fires is directly related to; (1) the oxidation properties of the particular solvent, (2) the air velocity through the bed, and (3) the design of the tank containing the activated carbon.[7] Fires are predominantly associated with ketone solvents and are most likely to occur after fresh carbon is added to the bed.[8] Ketone solvents are the predominant solvent used in this industry. To safely use ketone solvents continuous monitoring of the following factors is recommended: (1) the CO/CO_2 concentration, (2) the outlet adsorber temperature, (3) the steam flowrate, and (4) the performance of the air valves.[9] In the FVC&P industry most gas streams are humidified prior to entering the bed to minimize overheating of the bed.[3,4] The humidity is generally kept above 60 percent.[3]

While all of these operating problems mentioned above seriously affect the economics and ease of operation of carbon adsorption, they can be overcome. Most of the systems currently operating have only recently been installed. These modern control devices should have the design features necessary to solve the problems mentioned.

4.1.1.3 Existing Applications and Performance of Carbon Adsorption. The industry survey found four carbon adsorption units in operation in the vinyl coating and printing industry. Most of these units were installed during the last five years and, therefore, are representative of relatively modern technology. Two of these units will be described in detail to illustrate the applicability of carbon adsorption to the FVC&P industry.

Vinyl Coater A installed a new carbon adsorption system in 1977 to control VOC emissions from their solvent-based vinyl printing operation. The solvents recovered by the system are MEK, MIBK, acetone, and toluene. Separation of the solvent mixture is accomplished by dehydrating the mixture with solid caustic soda and distilling it through three bubble cap tray columns.

The unit is designed to handle approximately 2130 dry standard cubic meters per minute (76,140 scfm) of oven exhaust gas. Fugitive emissions captured by floor sweeps are ducted to the atmosphere. The system is designed so that the operator could maintain the inlet gas stream at a concentration of 40 percent of the Lower Explosive Limit (LEL). However, the plant normally operates at 15 percent LEL. Automatic hydrocarbon sensing devices activate a warning signal to the operator at 50 percent LEL and the equipment is shut down at 60 percent LEL.[3]

The control system consists of two banks of carbon adsorption units operated in parallel. Each bank is made up of three fixed carbon beds. At any given time one carbon bed is adsorbing, one is regenerating, and one is cooling. Cycle change is automatically initiated when the combustible gas monitor (in this case an infrared stack gas analyzer) on the adsorber outlet exceeds the breakthrough setpoint or when a programed time interval has elapsed. The inlet solvent-laden air stream is always filtered, cooled, and humidified before entering the carbon adsorber. The humidity is kept above 60 percent to minimize overheating of the bed (which helps prevent bed fires). The carbon beds are regenerated with steam, and the combined steam/solvent vapors are condensed. The condensate is then decanted with the solvent layer being sent to a distillation column and the water layer being steam stripped and discharged to a waste pond.

The system manufacturer has guaranteed an overall carbon bed recovery efficiency of 98 percent. This results in no more than 5 ppm of VOC in the exhaust stream for 90 percent of the time and no more than 50 ppm for 10 percent of the time. The average VOC emission rate was estimated to be less than 3.11 kg (6.86 pounds) per hour.[3]

No major operating problems have occurred in this VOC control system. Only routine maintenance procedures have been required on the system. Although it has not caused any system operational problems, the plant does have some carryover of plasticizer material into the solvent recovery system.[10,11] Plasticizer material is being entrained in the gas stream entering the carbon adsorption device. The material does not plug the carbon bed because it is desorbed during the bed's regeneration cycle. Following desorption from the carbon bed, the plasticizer material is transmitted into the distillation system. Wastewater discharged from the distillation column contains varying amounts of the plasticizer material. The plasticizers are recovered by decanting the water. The company currently secures the plasticizer material in storage drums and landfills it.[11]

Vinyl Coater B is also operating a carbon adsorption system for VOC reduction, however, this system attempts to control both oven and fugitive emissions. The system was installed in 1979 to control MEK solvent emissions from a 76.2 centimeter (30 inch) wide vinyl printing line.[12]

The carbon adsorption unit is designed to handle inlet solvent-laden air flows of 220 dscm/min (8,000 scfm). The concentration in the inlet gas stream was designed to be approximately 4500 ppm MEK (25% LEL). With these operating conditions, the carbon bed has a vendor guaranteed minimum removal efficiency of 95 percent. The adsorption system has a solvent recovery capacity of 363 kg (800 lbs) per hour.

Vinyl Coater B uses two fixed bed adsorbers to recover solvent. Each bed contains 2700 kg (6000 lbs) of activated carbon. Prior to entering the carbon beds, all solvent-laden air is filtered, cooled, and humidified. One unit is always on line adsorbing for a 55 minute cycle. The regeneration cycle of the other unit is 45 minutes (allowing ten minutes for cooling). Approximately 907 kg (2000 lbs) of steam per hour at 2 psig are used to regenerate the solvents. Following regeneration the solvent/steam mixture is condensed, adjusted for pH, and sent to a storage tank. From storage the solvent/water solution is sent through a distillation column and from there to a calcium chloride dehydration unit to purify and recover the solvent components.[12]

The wastewater discharges from the carbon adsorption and distillation systems used in the flexible vinyl printing industry represent potential sources of secondary environmental impacts. Depending on the particular situation being controlled, wastewater discharges from these systems would contain varying amounts of dissolved VOC.

Industry representatives have indicated that the BID cost analysis in Chapter 8 should include costs to cover the treatment of these wastewater discharges. No costs have been included for this purpose because none of the FVC&P plants currently operating carbon adsorption/distillation solvent recovery systems have reported any instances where such treatment of this wastewater stream is performed. The BID analysis suggests that the wastewater stream can be used as boiler feedwater. It is recognized that such wastewater streams may need to be deaerated and treated before reusing them in a boiler. If such boiler water treatment is not available or adequate, then the condensate could possibly be used as make-up for water cooling towers. Manufacturers in this industry are currently discharging these wastewaters to municipal sewers without local penalties or surcharges.

Local regulations may require treatment now or in the future. In such cases several low cost options are available. The recovery and solvent purification methods should be selected after considering the requirements of local water regulations.

These two examples illustrate the range of carbon adsorption applicability to the vinyl coating and printing industry. In other cases, however, other control options may be more attractive from an economic viewpoint. The ability to reuse the recovered solvent is the key issue in the economic assessment. Although there are a number of potential operating problems associated with carbon adsorption, these problems have been overcome in several industrial applications of this technology. Where carbon adsorption is economically attractive, it presents a good control option in terms of both environmental factors and resource conservation factors.

4.1.2 Incineration

The process of incineration involves the oxidation of organic pollutants to carbon dioxide and water. Incineration has been used extensively as an emission control technology in many industries, but not in the FVC&P industry. It is a mature and well-documented technology. This section presents a brief discussion of incinerator operation with emphasis on those factors that affect its application to FVC&P emissions because it may be considered for future applications.

4.1.2.1 Operating Principles. The operating principle of incineration is basically just oxidation (or burning) of the pollutants. In thermal incineration, this is accomplished by raising the solvent-laden air temperature to 540 to 820°C (1000 to 1600°F) or exposing same to a direct flame, both for a period of 0.3 to 0.75 seconds.[13,14] The percent of VOC (solvent) destruction as a function of temperature has been well-documented. Figure 4-4 shows the EPA's estimates of VOC reduction versus firebox temperatures.[14] Similar results can be achieved by catalytic incineration at lower temperatures (400° to 540°C or 750° to

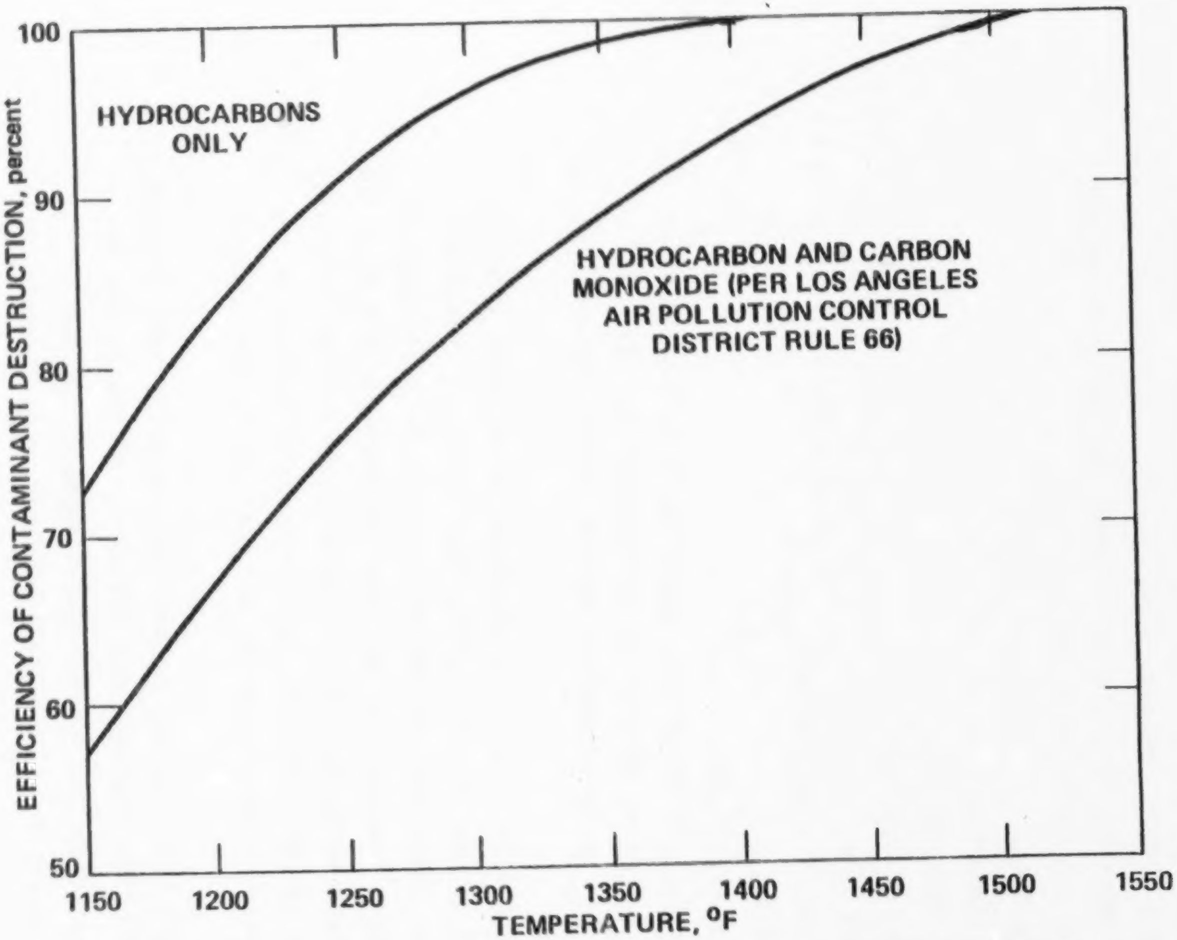


Figure 4-4. Typical effect of operating temperature on effectiveness of thermal afterburner for destruction of hydrocarbons and carbon monoxide.

1000°F).[15] In this study only one FVC&P manufacturer was identified that operated an incinerator for VOC control. The estimated destruction of VOC from this unit was 99 percent.[3]

Typical thermal and catalytic incinerators are shown in schematic form in Figures 4-5 and 4-6, respectively.

The factors important to incinerator design and operation include:

- type and concentration of VOC,
- gas flow rate,
- preheat temperature,
- firebox temperature,
- supplemental fuel rate,
- residence time,
- efficiency of flame contact,
- burner type, and
- amount of excess air.

The first four factors are the primary operating variables, and they determine the fifth factor, the rate of supplemental fuel firing. The remaining factors are design parameters and are subject to variations on a day to day basis.

Heat exchange equipment could be considered an optional accessory to the incinerator system, but with rising fuel prices, it has almost become a necessity. Heat recovery equipment is generally divided into primary and secondary recovery. Primary heat recovery is defined as the exchange of heat between the hot incinerator effluent and the relatively cool process waste stream. Secondary heat recovery is defined as any further exchange between the incinerator effluent and another process stream.

In describing a heat recovery system, the term efficiency is often used. This should be the thermodynamic efficiency of the system, or in other words, it represents the percent of available energy that is recovered. For a single air-to-air heat exchanger, this thermal efficiency may be approximated by:

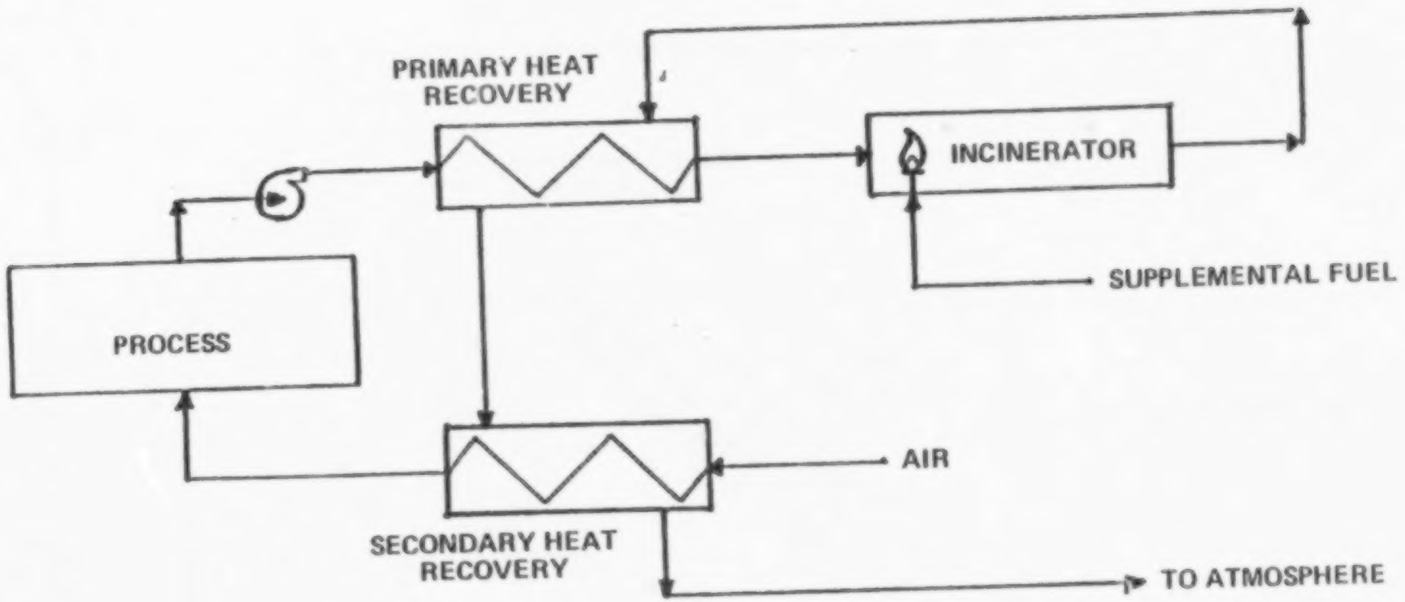

PRIMARY HEAT RECOVERY
INCINERATOR
SUPPLEMENTAL FUEL
PROCESS
AIR
SECONDARY HEAT RECOVERY
TO ATMOSPHERE

Figure 4-5. Incineration with primary and secondary heat recovery.

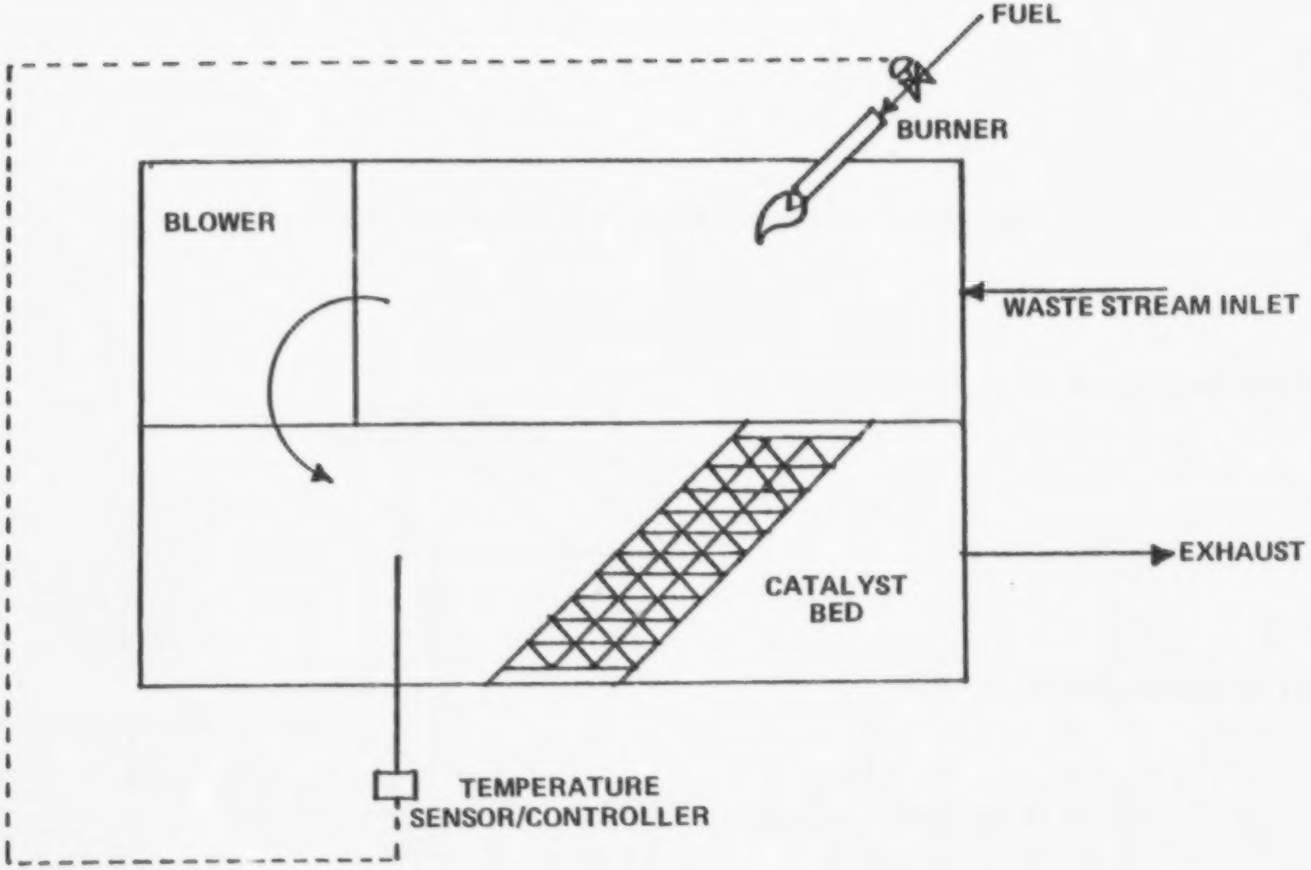

FUEL
BURNER
BLOWER
WASTE STREAM INLET
EXHAUST
CATALYST BED
TEMPERATURE SENSOR/CONTROLLER

Figure 4-6. Schematic diagram of a catalytic incinerator.

$$\text{Exchanger Efficiency} = \frac{T_3 - T_2}{T_1 - T_2}$$

where T_1 = Inlet Temperature - Hot side
T_2 = Inlet Temperature - Cold side
T_3 = Outlet Temperature - Cold side

Primary heat exchanger efficiencies (using standard tube and shell heat exchangers) are limited to about 45 percent efficiency not by heat exchanger design, but by safe operating practice. At 25 percent of the LEL, a temperature rise of up to 380°C (680°F) can occur on combustion. A maximum operating temperature of 820°C (1500°F) is typically specified to protect the incinerator and the heat exchangers.[16] This then limits the incinerator inlet temperature to about 440°C (790°F). This incinerator inlet limitation then limits the potential primary heat recovery efficiency. This also minimizes the possibility of auto-ignition of the waste stream in the primary heat exchanger. These primary heat recovery limitations are based on a concentration of VOC at 25 percent of the LEL. For lower concentrations, the safe limit for primary heat recovery increases. Below 5 percent of the LEL, 100 percent heat recovery would be safe, but technologically impractical.

Primary heat recovery in a catalytic incineration system is limited to a lower temperature by catalyst sintering and deactivation. The available heat in the incinerator exhaust is also lower, however, because of less sensible heat in the low temperature combustion products. This results in about the same primary heat recovery efficiency as thermal incineration.

Secondary heat exchange recovers waste heat for use in other processes in the plant. This energy may be used for process air heat requirements or for plant space heating. In coating facilities, secondary heat recovery could be used to heat inlet air to the drying ovens. Heat exchanger efficiencies in secondary heat recovery are typically in the 50 to 55 percent range.[17] Assuming a primary heat recovery efficiency of 35 percent, this would yield an overall heat recovery efficiency of 70 to 80 percent.

It is possible for the energy recovered from solvent incineration to provide all of the energy needed for the incinerator and the drying oven, with supplemental fuel required only for a small pilot burner to prevent flame-out. This is, of course, highly dependent on the concentration of the VOC in the oven exhaust. No supplemental fuel will be required to incinerate air streams at 40 percent LEL or higher, while a more conventional concentration of 25 percent LEL will almost always require supplemental fuel. The exact break-even point will vary with solvent type and the desired firebox temperature. The maximum percent LEL is normally dictated by the company insuring the oven.

It should be pointed out that even for lower concentrations where some supplemental fuel is required, additional heat is available in the stack gases for further heat exchange. This is dependent on the availability of another heat requirement in the immediate area. Some possibilities for additional secondary heat recovery would include space heating for the building, boiler combustion air preheat, and oven heat for other coating lines. If the heat in the incinerator exhaust were used to the fullest extent, a net energy savings over the uncontrolled situation would result even if the incinerator requires supplemental fuel.

4.1.2.2. Operating Problems. While incinerators are simple, reliable, and not prone to extensive operating problems, some of the potential problem areas include:

- fouling of heat transfer surfaces,
- corrosion,
- catalyst poisoning,
- secondary emissions, and
- high operating cost with low LEL gas streams.

The fouling of heat transfer surfaces is not a problem during incineration of VOC gas streams. These VOC streams exit from the printing and topcoating ovens and contain essentially zero particulates.

Halogenated hydrocarbon solvents will produce highly corrosive compounds when combusted. This problem is not significant in the FVC&P industry because halogenated hydrocarbon solvents are seldom used. An additional cause of corrosive atmospheres is the firing of supplemental fuels with a high sulfur content.

There are more potential problems with catalytic incineration than with thermal. The most serious of these problems is catalyst poisoning or deactivation. Some common catalyst poisons include phosphorous, bismuth, arsenic, antimony, mercury, lead, zinc, and tin.[18] Caution should be used in a catalytic incineration system concerning the use of phosphate metal cleaning compounds and galvanized ductwork.

A second problem in catalytic incineration is one of particulate matter. Combustion efficiency is reduced by inhibited contact between the catalyst active sites and the pollutant gases due to particulate buildup on the catalyst bed. Also, pressure drop is increased which increases utility requirements of the blower.

Any combustion source can potentially cause emissions of unburned hydrocarbons, carbon monoxide, and nitrogen oxides. The emission levels of these secondary pollutants should be very low considering that an incinerator is designed specifically with complete combustion as the objective. The typical operating temperatures of incinerators in the FVC&P industry will not promote significant oxidation of nitrogen in the combustion air to nitrogen oxides. Therefore the magnitude of any secondary pollutants from incineration is outweighed by the benefits of VOC reduction.

Dilute VOC streams can cause increased operating costs for incineration units. Dilute streams result from air leakage into the gas ducting systems, the dilution of oven gases with other process gases, or poor turndown in process ovens. Air leakage can be minimized by proper maintenance of ducts and ovens. The dilution of solvent-laden, oven gases occurs when dilute VOC streams, such as those from fugitive control equipment or curing oven zones, are combined directly with the drying oven gases. This problem can be minimized through efficient oven design where dilute VOC streams are used as makeup air to solvent drying zones in the oven.

A major operational problem with using incinerators on flexible vinyl printing lines is the 40 to 60 percent downtime[19] inherent in the printing operation. This high downtime is a result of: short production runs (many pattern changes), a need for consistent color matching, and a need for precise color and pattern registration. The operation of an incinerator at these 40 to 60 percent downtime conditions would be very inefficient and very costly because of the need to provide large amounts of supplemental fuel. However, in the absence of concentrated VOC going to the incinerator (during downtimes), supplemental fuel would be required to keep the incinerator running at an adequate solvent destruction temperature. The temperature of the incinerator cannot be allowed to drop (during downtimes) because once the line is operating again and emitting VOC, the incinerator cannot respond quickly enough from cold status to achieve solvent destruction temperatures.

4.1.2.3 Existing Applications and Performance of Incineration. The industry survey indicated that only one FVC&P facility uses an incinerator to control VOC emissions. The incinerator used by Vinyl Coater A is not designed to control VOC emissions from vinyl printing operations. The primary function of the incinerator is to control VOC emissions from an accompanying pressure sensitive adhesive coating line used to produce the final product. The incinerator can be used for VOC control of the vinyl lines if the carbon adsorber, normally used, malfunctions.

This thermal incinerator is designed to handle 550 dscm/min (19,700 scfm) of solvent laden air. It operates at 760°C (1400°F) and is expected to achieve a 99 percent destruction rate of VOC. Natural gas is predominantly used to fire the incinerator, but No. 2 fuel oil can also be used. Currently, this manufacturer does not recover any heat from the incinerator, although the idea is under consideration.[3] No major operating problems have occurred with the incineration system.

One other major manufacturer in the FVC&P industry is considering the installation of a thermal incinerator to control VOC emissions. Incineration is being considered instead of carbon adsorption because the LEL need not be as high as for solvent recovery methods, mixed solvents can be handled easily, and energy recovery benefits are possible.[20]

4.1.3 Wet Scrubbing

Wet scrubbers or wet collectors are in prominent use as air pollution control devices in many varied industries. The theory and technology behind wet scrubbing is well-developed and well-documented in the literature. Most simply a scrubber is a device which uses an aqueous stream or slurry to remove particulate matter and/or gaseous pollutants from an industrial process gas stream. In the vinyl coating industry scrubbers are used to control VOC emissions from flexible vinyl printing lines.

The survey of the vinyl coating and printing industry found three companies using wet scrubbing techniques to control VOC emissions. All three companies use packed tower or packed column scrubbers to reduce their VOC emissions and to control a related odor problem. The following sections, therefore, explain the general operation of packed column scrubbers for VOC control and their specific applications in the FVC&P industry.

4.1.3.1 Operating Principles. Packed columns are vertical structures containing manufactured packing elements such as raschig rings, spiral rings, lessing rings, berl saddles, and intalox saddles.[21] The columns control gaseous pollutants (solvent vapors) by absorbing them in a liquid medium. Solvent removal is initiated when the polluted gas stream enters the distributing space at the bottom of the column (below the packing area) and flows upward through the packing interstices. As the gas flows up through the packing, a scrubbing liquid is introduced at the top of the column and flows down over the packing counter to the gas flow. When the gas and liquid streams contact, the gaseous pollutants are absorbed into the liquid from the gas. The packing material aids in the absorption process by providing a large contact area between the liquid and gas streams. Figure 4-7 illustrates the arrangement of a typical packed column scrubber.[22]

Figure 4-8 illustrates the various types of packing elements used in conventional packed columns.[23] Packings are used to increase column stability, to reduce liquid channelling, and to increase surface area utilization.[21] Packing elements generally vary in diameter from 0.65 cm (0.25 in) to 7.6 cm (3 in). As the size of packing elements increases, the area of wetted surfaces decreases; thereby resulting in an efficiency reduction.[24] The more desirable properties of packing elements are given below:

- high surface area per unit volume,
- high ratio of effective area to total area,
- high percentage of free space,
- irregularity of shape,
- favorable liquor distributing qualities,
- low pressure drop, and
- durability.[21]

Another factor affecting VOC reduction is the method of liquid distribution inside the column.[25] Plates stationed in the packed column determine the efficiency of distribution. If the absorbing liquid is not evenly distributed at the top of the packed column, the VOC control efficiency will be considerably reduced. As the liquid flows down the column, it tends to flow towards the side walls. To counteract this occurrence and to maintain column efficiency, liquid redistribution systems are used.[24]

The primary reasons packed column scrubbers are used for VOC control include the following:

- high absorption efficiency,
- inexpensive corrosion resistant construction,
- extensive application experience,
- simplicity of installation, and
- availability in standard sizes.[26]

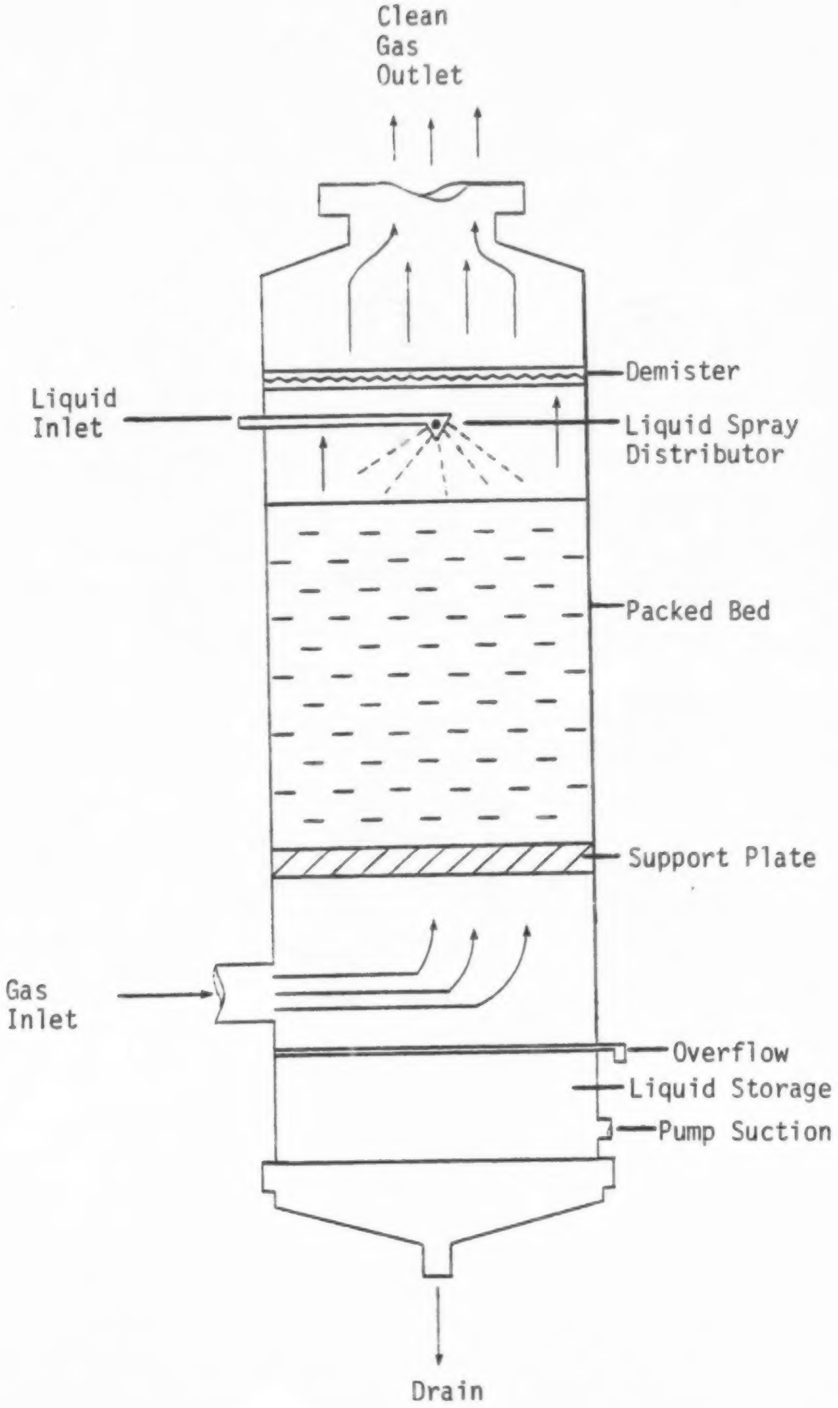

Clean Gas Outlet
Demister
Liquid Inlet
Liquid Spray Distributor
Packed Bed
Support Plate
Gas Inlet
Overflow
Liquid Storage
Pump Suction
Drain

Figure 4-7, Typical Packed Column Scrubber

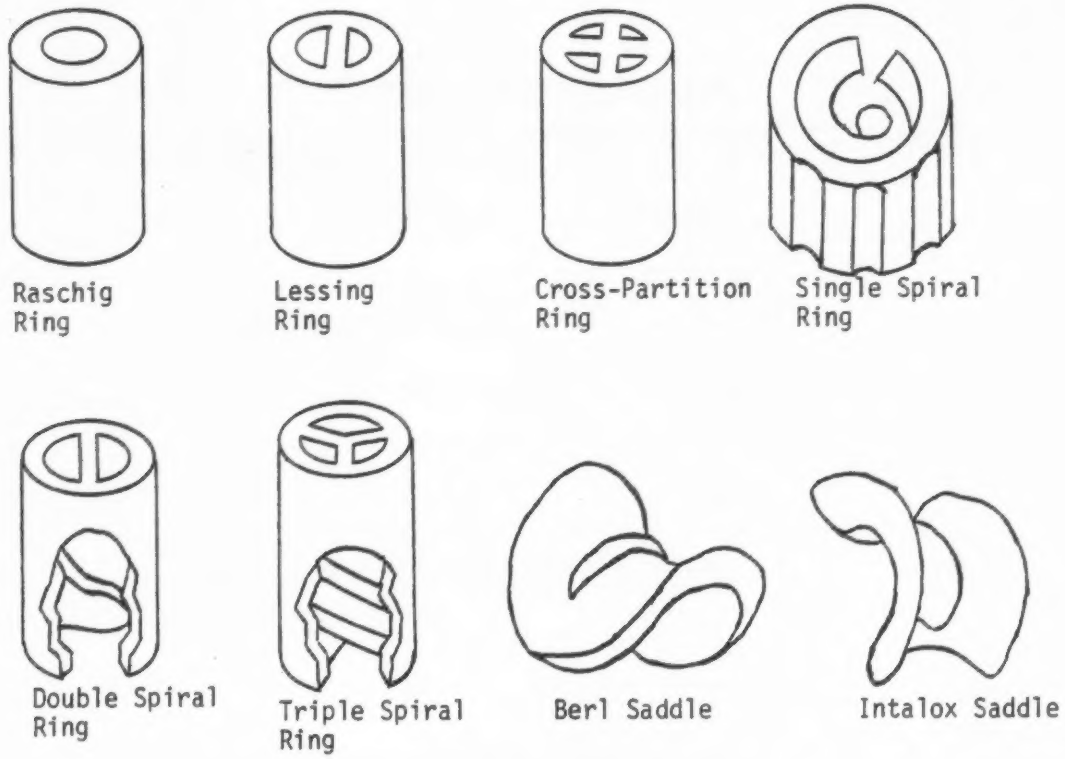

Raschig Ring
Lessing Ring
Cross-Partition Ring
Single Spiral Ring
Double Spiral Ring
Triple Spiral Ring
Berl Saddle
Intalox Saddle

Figure 4-8. Common Packings Used In Packed Column Scrubbers

4.1.3.2 Operating Problems. Packed column scrubbers have to be operated within a narrow range of conditions to avoid maintenance problems. If either the liquid or gas flow rates are accelerated, the loading point of the column is eventually reached. The loading point is defined as that point at which liquid hold-up starts increasing, thereby, resulting in increased pressure drop across the column. The acceleration of gas velocities beyond the loading point will cause a flooding condition. Flooding conditions generally cause high pressure drops and the entrainment of absorption liquid in the gas stream.[24]

In some applications of packed column scrubbers the build-up of solids in the packing becomes a serious operating problem. Solids in a column can be caused by particulate material in the gas stream and by absorption reaction precipitates.[24] Clogged packings could disrupt even liquid distribution and consequently lower the column VOC absorption efficiency. Cleaning solids build-up in most packed columns is difficult due to the inaccessibility of the column internals. Solids build-up is generally not a problem for packed columns used in the FVC&P industry.

4.1.3.3 Existing Applications and Performance of Wet Scrubbers. Three applications of wet scrubbers for VOC control were found in the FVC&P industry survey. Two of these cases will be discussed so as to demonstrate the applicability of this control method in the FVC&P industry.

Vinyl Coater Y prints and laminates purchased vinyl sheet to produce shower curtains and table cloths. Chlorophenol, MEK, and MIBK are the primary solvents used to formulate the company's printing inks. In a totally uncontrolled status the plant emits 6.3 kg/hr (13.8 lb/hr) of MEK, 0.22 kg/hr (0.48 lb/hr) of MIBK, and 0.012 kg/hr (0.027 lb/hr) of chlorophenol. Because of solvent emissions the plant has a discernible odor problem beyond their property line. In 1975 the company installed a wet scrubbing system to control these solvent emissions.[27]

The control device installed by the plant was a cylindrical, single stage, vertical packed column scrubber. The MEK, MIBK, and chlorophenol vapors are removed from the gas stream by absorption in chemically treated water. The water is treated with caustic soda and sodium hypochlorite for odor control purposes. Generally about 45 liters (12 gallons) of water are used per 28.3 cubic meters (1000 cubic feet) of gas. The liquid recirculation rate in the absorption column is about 90 to 95 percent.[27]

The scrubber is designed to handle 260 dscm/min (9300 scfm) of air at a temperature of 29°C (85°F). The design gas velocity of the unit is 1.5 m/sec (5 feet/sec). The overall scrubbing efficiency is about 90 percent. The waste scrubber liquid, containing the solvents, is diluted with other sewer water and is discharged to a municipal sewer.[27]

Vinyl Coater Z also prints and laminates PVC film in a manner very similar to Vinyl Coater Y. The solvents used by Coater Z include MEK, MIBK, and toluene. Before controls were installed in 1973 the plant was emitting about 23.6 kg/hr (52 lb/hr) of ketone solvents and 14.5 kg/hr (32 lb/hr) of toluene. Complaints about plant odors beyond the property line were also a problem.

The VOC control system of Coater Z consists of an air ventilation system operated in conjunction with a wet scrubbing device. On the print lines a system of slot type ducts provides an air sweep over the coated fabric rolls and the coating application areas. In this plant the air sweeps from three printing machines are ducted together and sent to the scrubber. The scrubber is a two stage, cross flow packed device designed to handle 390 dscm/min (13,800 scfm) of solvent-laden air at an inlet temperature of 24 to 27°C (75 to 80°F). Stage one of the scrubber recirculates a dilute aqueous alcohol solution, while stage two recirculates a dilute aqueous solution of an emulsifying agent. A diagram of the scrubber is shown in Figure 4-9.

The scrubber is designed to remove MEK, MIBK, and toluene vapors from the entering air stream by absorbing them in water to which aliphatic alcohol has been added. Alcohol is added to increase solubility, especially of MIBK. Toluene vapors are solubilized in a dilute emulsifying agent solution. In stage one of the scrubber about 34 liters/min (9 gal/min) of liquid are required per 28.3 cubic meters (1000 cubic feet)

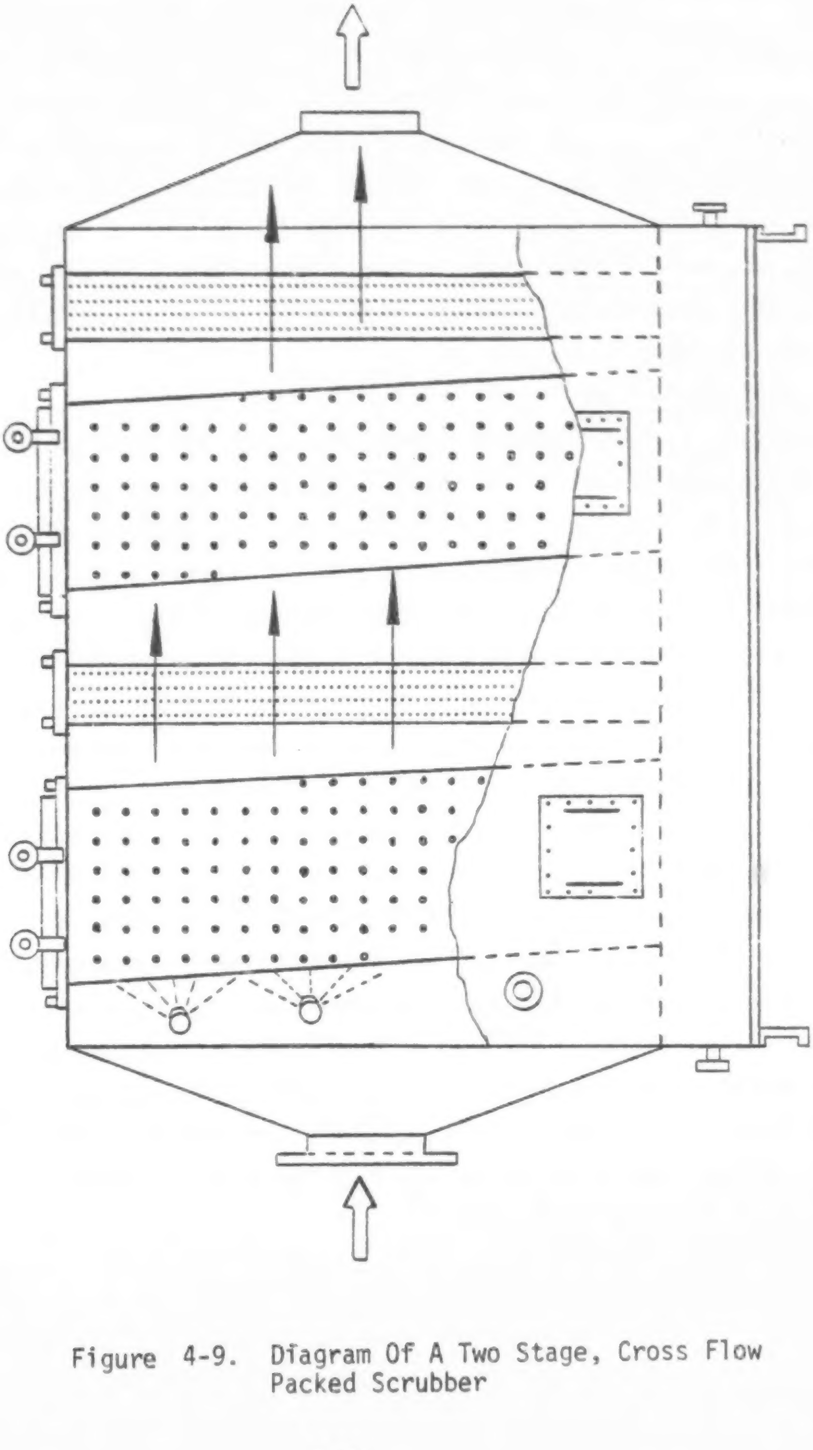


Figure 4-9. Diagram Of A Two Stage, Cross Flow Packed Scrubber

of solvent-laden gas. In stage two (toluene removal), only 26.5 liters/min (7 gal/min) of liquid are needed for every 28.3 cubic meters (1000 cubic feet) of air to be cleaned. The efficiency of the scrubbing device is 90 percent. No data on overall plant VOC reductions were available.[27]

The amount of waste scrubber liquid that is discharged from this facility into a municipal sewer is very small. The discharge load is reduced because the facility continually recycles the majority of the water used by the scrubbing system. Only a small bleed off stream of two gallons per minute is discharged from the system into a municipal sewer. The remainder of the scrubber liquid goes into a recycle tank, where after the addition of treatment chemicals, it is pumped back to the scrubber for reuse.

4.1.4 Condensation Systems

Condensation is a VOC control technology which may also be applied to vinyl coating and printing operations. This technology could be applicable to control drying oven VOC emissions, but generally not fugitive VOC. One major manufacturer of printed vinyl has stated that they are installing inert air condensation systems on two print line ovens as a retrofit technology to meet state VOC standards.[28] No other commercial vinyl coater identified in this survey is using a condensation system to control VOC emissions. However, in 1979 a condensation system vendor performed pilot plant tests on a fabric coating facility to determine an overall recovery efficiency figure for a solvent-based surface coating operation. In these tests the condensation system itself had a recovery efficiency of 99.9 percent.[29] By using the condensation system, operating costs at the pilot facility were reduced more than 70 percent below what would be expected from a conventional solvent drying oven system. Savings were achieved by: 1) eliminating the energy needed to heat dilution air, 2) lowering the energy consumption of the oven, and 3) receiving a credit for recovered solvent.[30] The fabric coating company plans to scale up the pilot program to control their commercial lines by early 1980.[29]

4.1.4.1 Operating principles. Inert gas condensation is an emerging solvent recovery technology. Although most companies offering this technology have their own proprietary recovery processes, a general description of condensation systems can be made. Figure 4-10 shows a typical condensation system design currently being marketed.[29]

Nitrogen is used as the inert gas in many of these condensation systems. Gaseous nitrogen is used to provide inert oven atmospheres and liquid nitrogen is employed as a refrigerant for condensation purposes. The inert oven atmosphere means all oxygen has been displaced from the system. The removal of oxygen allows the web to dry in an inert, nonflammable atmosphere with solvent concentrations much higher than those allowed in a conventional drying oven system.

Initially in the drying process the coated web enters the inert oven atmosphere. Heat and recirculated inert gases are used to dry the solvent from the coated web. Upon drying, a portion of the inert gas containing highly concentrated solvent vapors is ducted to a solvent recovery vessel. In the vessel liquid solvent is recovered by condensation in several stages of heat exchange. If necessary a final stage of heat exchange uses liquid nitrogen refrigeration to accomplish the desired recovery. Recovery rates of 99 percent are attainable.[30] The inert gas which has been stripped from the solvent is reused to keep the oven atmosphere balanced and inert. Inert gas vaporized from the liquid refrigerant is also used for balancing purposes.

To successfully use inert gas condensation the oven must be sealed from outside air, dust, and moisture. Oven sealing is generally accomplished through the use of nitrogen gas curtains. These curtains prohibit any leakage into the system, but a small quantity of nitrogen flows out of the oven. This necessary sealing process would limit the application of the condensation method to only drying oven emissions because captured fugitive emissions could not be ducted into the system. Condensation systems could not be used to achieve some of the regulatory alternatives presented in Chapter 6 because of the inability to control fugitive emissions. Because the drying oven is sealed and ventilation prohibited,

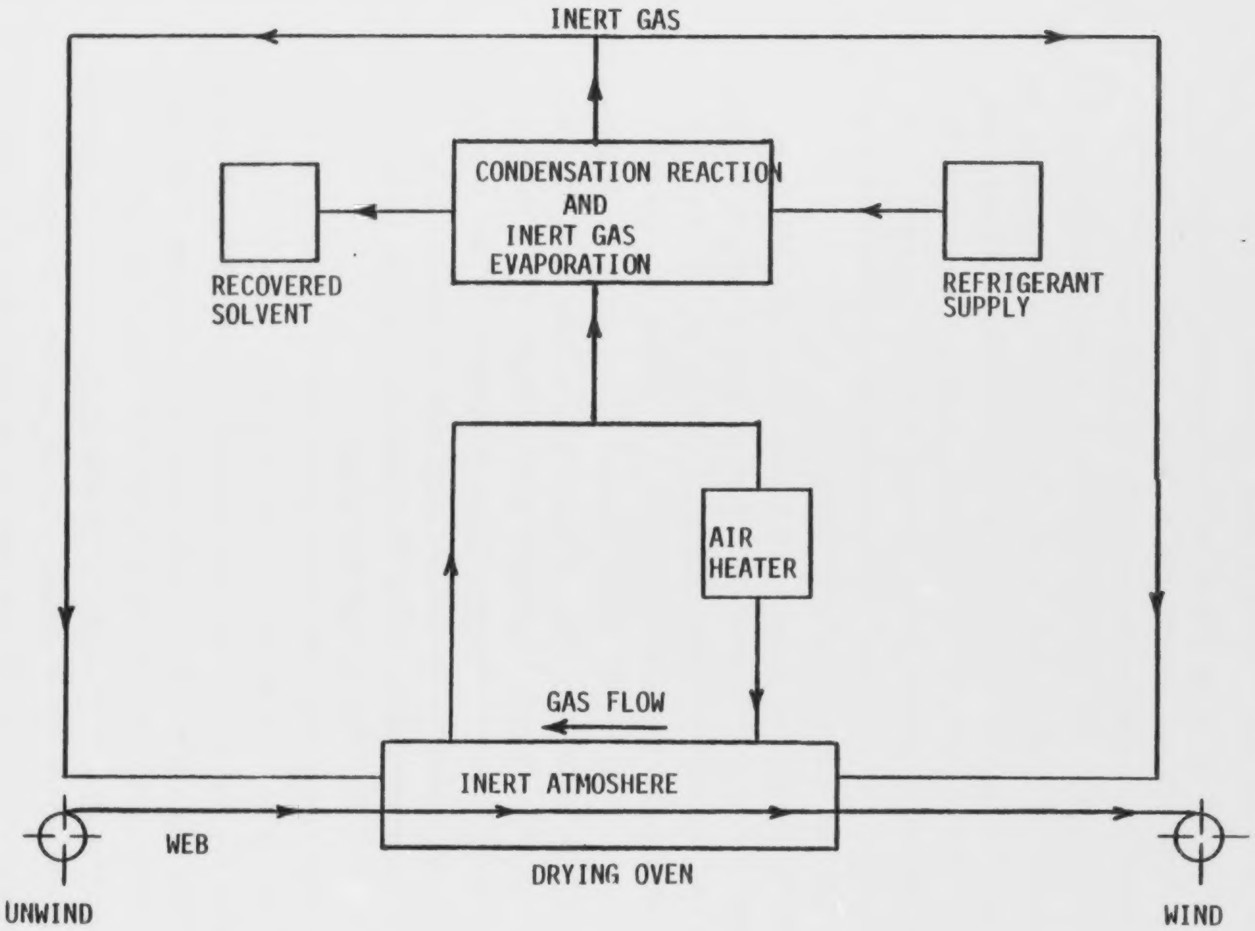

INERT GAS
CONDENSATION REACTION AND INERT GAS EVAPORATION
RECOVERED SOLVENT
REFRIGERANT SUPPLY
AIR HEATER
GAS FLOW
INERT ATMOSHERE
WEB
DRYING OVEN
UNWIND
WIND

Figure 4-10. Diagram of an Inert Gas Condensation Solvent Recovery System[29]

the drying atmosphere can readily be contained and recirculated. The internal recirculation allows heat energy to be maintained and solvent concentrations to rise. Heat is required only as is needed to evaporate the solvent and dry the product. Impingement velocities and the oven flow rate are then independent of heating and may be, according to system manufacturers, increased at no cost.[29]

One of the primary benefits of inert gas condensation systems is that they save energy. Manufacturers of these systems claim savings of 40 to 90 percent depending on the type of coating being applied.[30] The higher 90 percent figure applies where very light paper or plastic film substrates are being heated. The coating of materials like heavy-gauge steel will result in lower savings. Energy is saved because large volumes of oven dilution air do not have to be heated and drawn through the oven.

The main drawback to inert condensation systems is that they can only be used on webs that generally do not break (metal, fabric, or heavy paper or plastic). When a web breaks in a drying oven, operators must go into the oven and repair the break. To do this in inert systems the oven must first be purged of the inert gas atmosphere. This procedure is very costly and time-consuming to the operator. This limitation hinders the use of these solvent recovery systems on some high speed, thin web operations.

4.1.5 Vapor Collection Systems

The design of the vapor collection system is very important to the overall emission reduction from a given facility. Control equipment can only recover or destroy those emissions which are captured and routed to it. Fugitive emissions escape directly. Only proper collection system design can minimize these fugitive emissions. Fugitive VOC emissions from flexible vinyl printing facilities occur from: evaporated solvent in the ink troughs, the exposed part of the gravure printing cylinder, and exposed portions of the coated vinyl web prior to entering the drying oven.

An efficient collection system should maximize the capture of fugitive emissions while minimizing the capture of dilution air. Since these are opposing functions, there should be an optimum degree of collection. This section will identify those factors important in collection system design, and qualitatively address the optimum degree of collection.

The factors important to the efficiency of a collection system include:

- degree of turbulence,
- capture velocity,
- selectivity of collection, and
- degree of containment.

Although these factors are interdependent, each one will be discussed separately.

It is obvious that turbulence in the air around a fugitive emission source will make effective collection much more difficult. Sources of turbulence that should be recognized and minimized (within operating constraints) include:

- thermal air currents,
- machinery motion,
- material motion,
- operator movements,
- room air currents, and
- spot cooling and heating of equipment.

The velocity necessary to collect contaminated air and draw it into an exhaust hood is called the capture velocity. At capture velocity, the inflow of air to the hood is sufficient to overcome the effects of turbulence and thereby minimize the escape of contaminated air. Empirical testing of operating systems has been used to develop the guidelines for capture velocity presented in Table 4-1.[31]

The selectivity of a collection system is as important as its overall efficiency. Selectivity describes the ability of the collection system to capture pollutants at their highest concentration by mini-

Table 4-1. RANGE OF CAPTURE VELOCITIES

Condition of dispersion of contaminant	Capture velocity m/s (fpm)
Released with little velocity into quiet air	.25 - .51 (50-100)
Released at low velocity into moderately still air	.51 - 1.02 (100-200)
Active generation into zone of rapid air motion	1.02 - 2.54 (200-500)
Released at high initial velocity into zone of very rapid air motion	2.54 - 10.2 (500-2000)

mizing the inflow of clean air. A highly selective system will require less power to achieve a given collection efficiency, and the high concentrations can have a great benefit in the subsequent treatment of the collected vapor.

One method of improving selectivity is the use of flanges in hood design to minimize air flow from areas of low concentration. This technique can reduce dilution air by as much as 25 percent.[32]

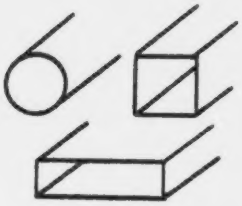
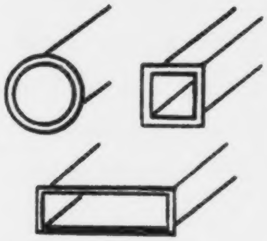
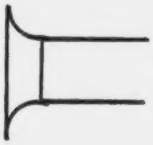
Flanges can also lower the pressure drop at the hood by altering its coefficients of entry (C_e). The value of C_e is a measure of the degree of turbulence caused by the shape of the opening. A perfect hood with no turbulence losses would have a C_e equal to one. Table 4-2 gives coefficients of entry for selected hood openings.[33]

The final and potentially the most important factor is the degree of containment that the collection system has around the source of emissions. Ideally that source should be isolated in an air tight container with all air exhausted into the collection system.

Several alternate hood designs are available for capturing vapors heavier than or about the same specific gravity as air. The first of these is the floor sweep, which, as the name implies, is a hood that takes suction near the source at floor level. Here again the web to hood distance is too large for very efficient collection. The slotted hood design remedies that. Here a slotted duct is run along each edge of the exposed web and draws air across the web into the hood.[34] In both the slotted duct and vacuum blanket controls, the captured VOC can be routed back into the drying ovens.

Routing or recycling VOC back into the drying ovens is a very efficient method of operating a VOC capture and control system. By recycling a VOC-laden air stream back into the drying ovens, higher VOC concentrations (as % LEL) can be maintained. Higher VOC concentrations being sent to the control device will result in better performance efficiencies and lower energy costs (when incinerators are used).

Table 4-2. COEFFICIENTS OF ENTRY FOR SELECTED HOOD OPENINGS

Hood Type	Description	C_e
	PLAIN OPENING	.72
	FLANGED OPENING	.82
	BELL MOUTH INLET	.98

Many variations or designs of VOC recycling are possible depending on the particular configuration of the print line. A typical recycling arrangement is shown in Figure 4-11. A portion of the VOC-laden air stream being exhausted from the drying oven is drawn off and sent to a burner for reheating. The heated VOC-laden air is reintroduced into the oven and can be used to dry the coated, wet web. By using recycled air, the VOC concentration to the control device can be increased because no additional outside air has to be brought into the oven. Additional outside air would dilute the VOC concentration below the level that 25 percent LEL to the control device could be maintained.

Another method that potentially could be used to obtain high VOC capture efficiencies is total containment of emissions. Total containment means that all print lines are enclosed in a room or structure which is maintained at a slight vacuum by drawing all required oven air from inside the room or structure. A booster blower would be used to move oven air exhausts on to a control device. This results in drying ovens which operate at a slight negative pressure with respect to the coating room. This type of totally contained collection system can approach 100 percent efficiency without diluting the VOC-laden air stream going to the control device.[6]

In contrast to totally enclosing the coating line (or coating room), some continuous web surface coating industries only enclose their coater to contain fugitive emissions. One of these companies is involved in coil coating operations and the other in zinc oxide paper coating. Each operation uses a totally enclosed structure around their coater. The structure itself contains the majority of escaping fugitives. Fans and hoods inside the enclosure are used to vent the fugitive emissions to the ovens and from there on to a control device.[35,36]

All web coaters using total enclosures reported satisfaction with their systems. No problems arose in connection with the operation of the coating line. In addition to capturing the fugitives for environmental purposes, the enclosure also acts as a safety mechanism. It reduces the potential for explosions and other hydrocarbon-related work

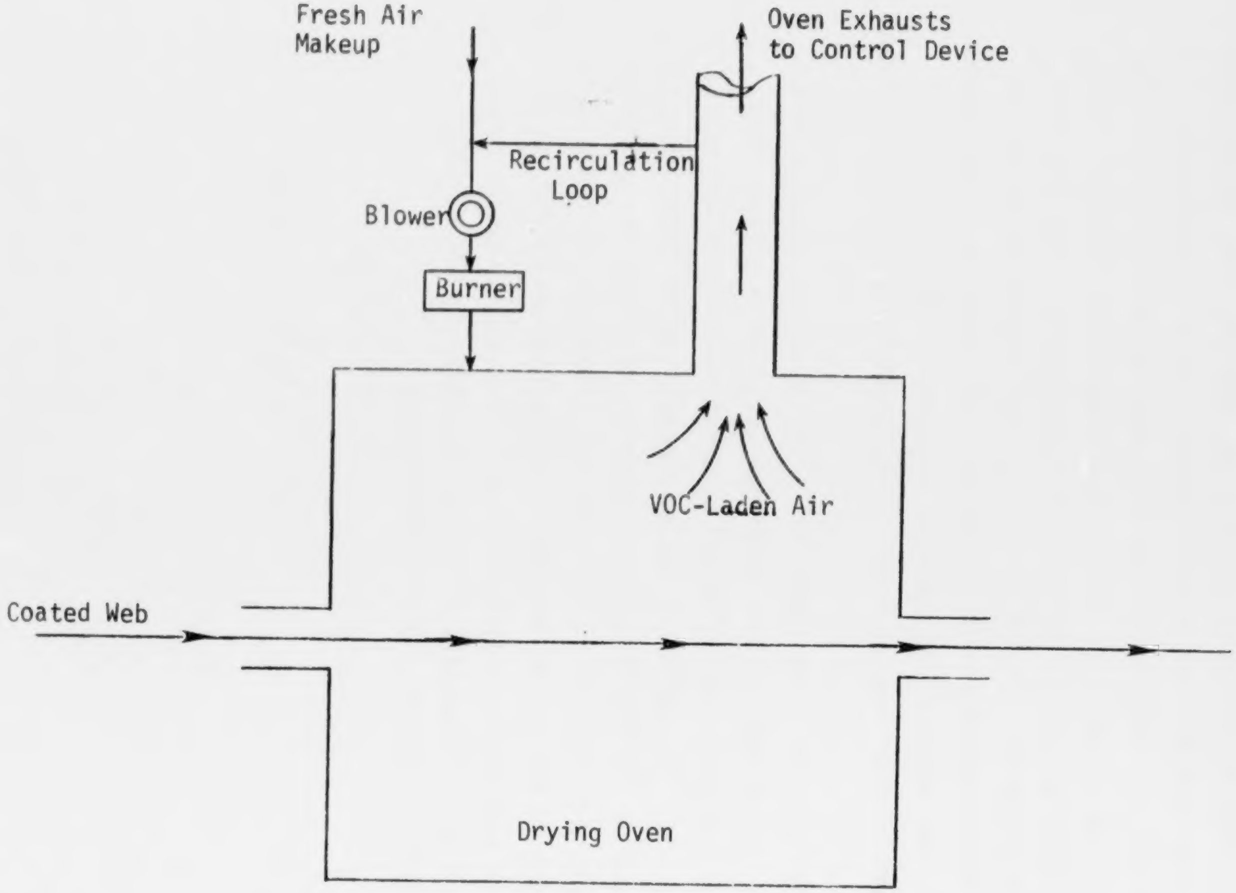

Fresh Air
Makeup
Oven Exhausts
to Control Device
Recirculation
Loop
Blower
Burner
VOC-Laden Air
Coated Web
Drying Oven

Figure 4-11. Basic Method of Recycling VOC-Laden Air Back to the Drying Oven

area problems. Through proper technology transfer, the vinyl coating and printing industry should be able to capture their fugitive emissions in a similar manner.

Although it does not use a total enclosure technique, the best controlled facility in the FVC&P industry has been designed and equipped with a very effective emission capture system. In this system each printing head and its associated dryer have been designed in conjunction with each other to achieve high levels of VOC emissions capture. This facility concentrates particularly on capturing fugitive VOC emissions. The ink supply drums and the ink pumping systems to each print station are closed, thereby greatly reducing fugitive VOC emissions from a print station. The near complete enclosure of the gravure rollers and the wet, coated web further reduces fugitive emissions from the print station area.[12]

Each print station is equipped with a drying plenum which extends down from the drying oven to just above the rotogravure rolls. This plenum captures fugitive VOC emissions evaporating from the wet web as it is being dried. The amount of wet web exposed to the atmosphere is greatly reduced by the drying plenum. Despite the attentions given to emissions capture at this facility, excellent visibility of the process and easy access to the coating equipment are maintained by the use of large, movable plexiglass covering panels.[12] The vapor capture system was determined to be 90 percent efficient in capturing VOC emissions from the facility's flexible vinyl printing line.

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5. MODIFICATION AND RECONSTRUCTION

While New Source Performance Standards (NSPS) are intended primarily for newly constructed facilities, existing sources can become subject to an NSPS through either "modification" or "reconstruction." These terms are defined in detail in 40 CFR 60.14 through 40 CFR 60.21. A modification is any change in an existing facility that results in increased emissions. A reconstruction is any change in an existing facility to the extent that the fixed capital cost of the new components is 50 percent or more of the fixed capital cost of a comparable entirely new facility. Examples of possible modification and reconstruction in the vinyl coating and printing industry are also discussed in this section.

5.1 MODIFICATIONS

EPA has promulgated general regulations in 40 CFR 60.14 for implementing Section 111 of the Clean Air Act with regard to modifications. As defined in these regulations, a modification is a physical or operational change to an existing facility which results in an increase in the emission rate to the atmosphere of any pollutant to which a standard applies.

Under the regulations, certain physical or operational changes are not considered to be modifications even though emissions may increase as a result of the change. It is stated in 40 CFR 60.14 that the addition or modification of one facility at a source will not cause other unaffected facilities at that source to be subject to NSPS provisions. Other exceptions or exemptions to the modification provision include:

- routine maintenance, repair and replacement,
- production increases achieved without any capital expenditure,

- production increases resulting from an increase in the hours of operation,
- use of an alternative fuel or raw material if the existing facility was designed to accomodate it,
- conversion to coal for energy considerations,
- addition or replacement of equipment for emission control (as long as the replacement does not increase emissions), and
- relocation or change of ownership of an existing facility.

The key criterion for a modification determination is whether actual emissions to the atmosphere have increased on a mass per time basis (kg/hr) as a result of the change. Changes in emission rate may be determined by the use of emission factors, or by material balances, continuous monitoring data or manual emission tests in cases where the use of emission factors does not clearly demonstrate that emissions do or do not increase. If any increase in emissions that would result from a change to an existing facility can be offset by improving an existing control system or installing a new control system for that facility, such a change would not be considered a modification (since actual emissions would not increase). However, emission decreases at other facilities at a plant cannot be considered when making a modification determination for a particular facility.

Once an existing facility is determined to be modified, it becomes an affected facility, subject to the standards of performance for the pollutant or pollutants which have increased due to the modification. All of the emissions of the pollutants which have increased must be in compliance with the applicable standards, not just the new emissions.

The following paragraphs will list potential modifications in the flexible vinyl coating and printing industry (FVC&P) and how they relate to the proposed NSPS.

The productivity of a FVC&P finishing line is determined by the web width, the line speed, the hours of operation, and the efficiency of scheduling. This industry has historically experienced a steady growth.

Production increases to accommodate that growth can be accomplished by two methods. In the first method, the operation of the existing equipment is pushed to its capacity by debottlenecking, more efficient scheduling, and increasing the hours of operation. When no more capacity can be achieved in this manner, new finishing lines are built or existing lines are upgraded. Most of the production increases (and the associated emission increases) from the first method are specifically exempted from NSPS compliance. Most of the equipment modifications in the second method involve totally new sources, or investments so large as to qualify as reconstruction. Specific examples are given below, with emphasis on the few cases where the modification clause might apply.

5.1.1 Changes in Web Width

Changes in the width of web would increase both production and emissions. The maximum web width that any given finishing line can handle is an integral part of the basic design of the line. Therefore, web width cannot be increased without installing essentially all new equipment. If an increase in web width were desired, it would normally be more attractive to build a totally new line than to modify an existing line. If such a modification were to be made, capital expenditures would be required and the work would fall under the reconstruction provisions.

5.1.2 Changes in Line Speed

An increase in line speed is the most likely change that could constitute a modification.[1] The maximum line speed for a given facility depends on both the basic design of the finishing line and on the specifications for each product. The factors which might constitute a line speed limitation include:

- a limitation on the available power and/or speed of the motors which drive the web,
- drying limitations based either on the amount of heat available or on residence time in the oven,
- a limitation on oven circulation which causes the Lower Explosive Limit (LEL) to be exceeded,

- a limitation on the maximum speed at which a smooth finish can be achieved, and
- a limitation due to fragility of the web.

For a given finishing line, the maximum line speed will differ between products, and the limiting equipment factor may differ also. Any equipment changes (such as larger/faster drive motors, higher capacity burners for the ovens, higher capacity oven circulating blowers, LEL sensors with alarm/shutdown capacity, or a change in printing stations which might be made to increase line speed) would require capital expenditure and result in increased emissions. As such, they might be considered modifications which would require that facility to comply with NSPS.

Many changes in production specifications (such as type of substrate, web, ink, or coat weight) could alleviate an equipment limitation resulting in a production increase. Some combinations of these changes could also result in increased emissions. They might not be termed modifications, however, since no capital expenditure would be required.

5.1.3 Changes in the Hours Available for Operation and/or Scheduling Efficiency

A typical FVC&P finishing line operates from 120 to 140 hours per week. Significant increases in production and emissions could result from extending the working hours, but this is specifically exempted under the modification clause.

Even during the hours of operation, a finishing line must often be shut down or slowed down. This might be done to remove a finished roll of product and add a fresh roll of substrate to splice a broken web, to make an adjustment at the print stations or to change inks or color pattern. Each time a change is made in the type of product to be coated or printed on a given line, time must be allowed to clean up the equipment and to reset the controls to the new product specifications. Any given FVC&P product potentially receives several different coats in its production (precoat, printcoat, topcoat). All of these factors indicate that careful scheduling can increase production which will result in increased emissions. This process might not be a modification because it requires no capital expenditures and no equipment modification.

5.2 RECONSTRUCTION

An existing facility may also become subject to new source performance standards if it is "reconstructed." As defined in 40 CFR 60.15, a reconstruction is the replacement of the components of an existing facility to the extent that 1) the fixed capital cost of new components exceeds 50 percent of the fixed capital cost of a comparable entirely new facility, and 2) it is technically and economically feasible for the facility to meet the applicable standards. Because EPA considers reconstructed facilities to constitute new construction rather than modification, reconstruction determinations are made irrespective of changes in emission rate.

The purpose of the reconstruction provisions is to ensure that an owner or operator does not rebuild an existing facility without consideration of the achievability of the standards of performance. Without such provisions, circumvention of the standards could be attempted by replacing all but vestigial components (such as, frames, housing, and support structures) rather than constructing a "new" replacement facility subject to the standards of performance. The reconstruction provisions prevent such a circumvention where it is technically and economically feasible to achieve the standards. If a facility is determined to be reconstructed, all of the provisions of the standards of performance applicable to that facility must be satisfied.

Many of the changes mentioned in the section of modifications would likely be high enough in cost to qualify under reconstruction. Any change of equipment to increase web width would require such massive equipment replacement that it would certainly require EPA's determination as to whether it would be reconstruction. It is doubtful that this would occur, however, since the plant could likely build a totally new line for the same expenditure.

Several of the equipment changes to increase line speed could conceivably be costly enough to require a reconstruction determination. This would be most likely in the case of a severe drying limitation which might require the addition of one or more oven zones. Many of the smaller investment options (such as higher capacity burners, larger circulating blowers, high speed drive systems, or instrumentation to allow operation at a higher percentage of the LEL) would not meet the guideline of greater than 50 percent of new construction cost. Combinations of these items could conceivably be costly enough to exceed 50 percent.

5.3 REFERENCES

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6. MODEL PLANTS AND REGULATORY ALTERNATIVES

The purpose of this chapter is to define the model plants and the regulatory alternatives that will be applied to them. The model plants represent typical expansions of existing facilities or typical new plants to be built in the vinyl coating and printing industry. The regulatory alternatives developed in this chapter represent various courses of action the EPA could take towards controlling VOC emissions from the vinyl coating and printing process. The environmental and economic impacts of these alternatives are examined in Chapters 7-9 for each model plant.

6.1 MODEL PLANTS

As discussed in Chapter 3, a variety of web widths, ink compositions, ink application rates, number of print lines and number of print stations are found in the vinyl coating and printing industry. A complete characterization of an industry as complex as the vinyl coating and printing industry would require many cases. The models presented here are an attempt to find a workable and meaningful set of cases.

Table 6-1 contains the configuration parameters of the model plants. Two web widths, 1.5 meters (60 inches) and 0.76 meters (30 inches), were chosen. The larger product width is commonly found in industry. The smaller product width allows representation of a small capacity plant or expansion.

The single print line model plants, A, B, and C, represent expansions and major modifications of existing plants or new, small plants. The multiple print line plants D and E represent new, large plants. There are many lines now in operation with less capacity than these models, however, it is thought unlikely that a line smaller than model C will be chosen for a new plant or to replace obsolete lines.

TABLE 6-1. MODEL PLANTS

Model Plant	Web[1,2,3,4,6,7,8,9] Width m (inches)	Number of Print Lines	Number[1,2,3,4,5,6,7,8,9] of Print Stations	Ink[1,6] Formulation
A	1.5 (60)	1	3	5% solids
B	1.5 (60)	1	6	5% solids
C	0.76 (30)	1	6	5% solids
D	1.5 (60)	6	18[a]	5% solids
E	1.5 (60)	6	36[b]	5% solids

---

[a] Three print stations per print line.

[b] Six print stations per print line.

Each print station applies one coating. Some products require up to six coatings and Model Plants B, C, and E reflect this. Other products require fewer coatings and Model Plants A and D, with three stations per print line reflect this. The three print station model is depicted in Figure 6-1.

Ink formulations used by industry range from 70 to 95 percent solvent, 5 to 30 percent solids, by weight. Emission control equipment must be designed to accomodate the highest solvent loading, therefore, the ink formulation was chosen to be 5 percent solids, 95 percent solvent.

More detailed information on the finishing process is given in Chapter 3 of this report.

6.1.1 Model Plant Parameters

The model plant parameters for the processes used in coated vinyl manufacturing are based on data from existing facilities in the vinyl coating and printing industry. Table 6-2 lists the parameters which are used to calculate material balances for the model plants. Each plant operates 6000 hours per year with the finishing process operating 60 percent of that time as shown in Table 6-2. This value is based on estimated, typical downtimes and production schedules for the finishing process.

Many existing print lines operate at slower line speeds than these models, however, it is thought that any new installations will utilize the higher speed equipment now available.

The solvent used in the finishing coatings for the model plants consists of 25 weight percent toluene, 25 weight percent methyl isobutyl ketone (MIBK), and 50 weight percent methyl ethyl ketone (MEK). Many of the coating formulas used by the FVC&P industry are more nearly one component formulas and often contain over ninety percent MEK. The solvent mixture chosen for the model plants requires complex distillation equipment in order to recover and purify these solvents. The industry also uses small quantities of 10 or 15 other solvents. It is generally not economical to purify or separate these because no single solvent represents more than one or two percent of the total solvent usage.

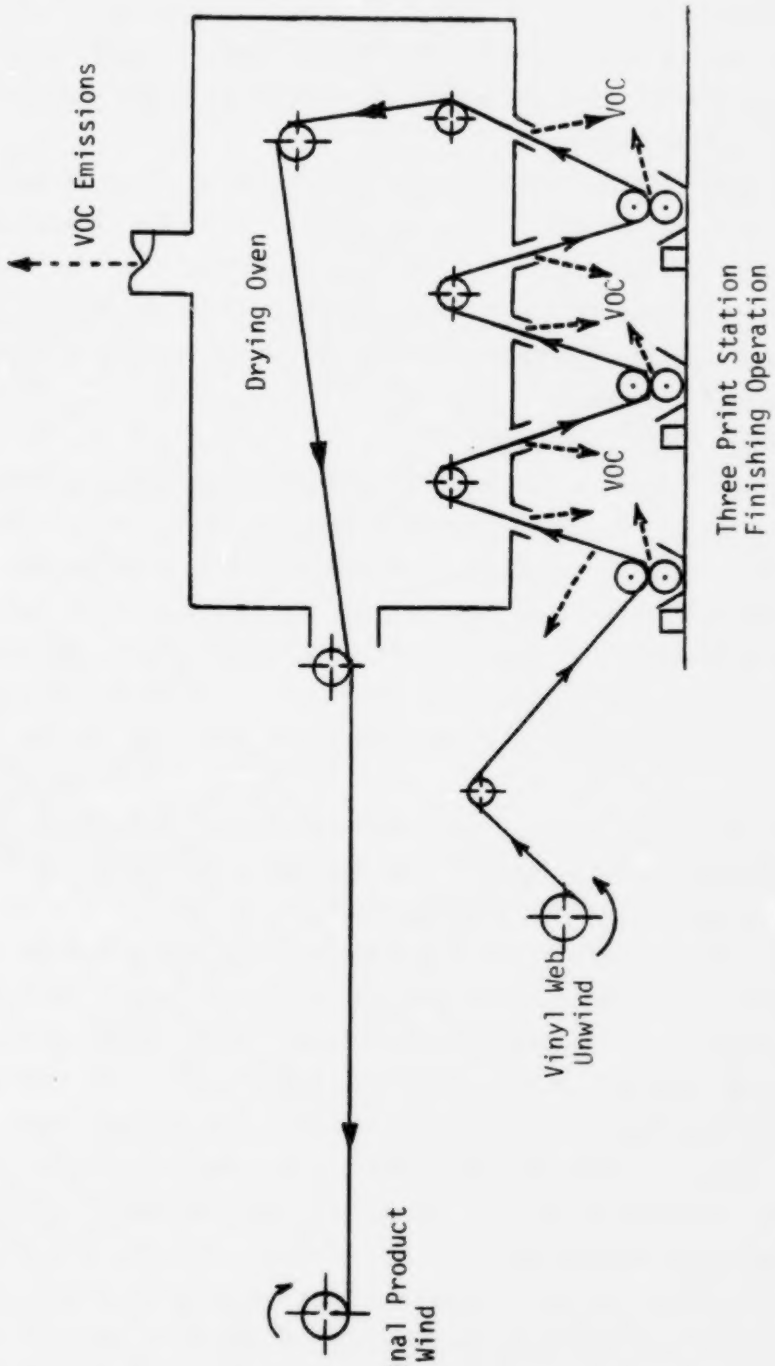
VOC Emissions
Drying Oven
VOC
VOC
VOC
Three Print Station
Finishing Operation
Vinyl Web
Unwind
Final Product
Wind

Figure 6-1. FINISHING LINE MODEL PLANT

TABLE 6-2. MODEL PLANT PARAMETERS FOR VINYL COATING PROCESSES

	Operating[1,6] Speed m/s	(ypm)	Annual[1,2,3,4,6,7,8,9] Operating Hours	Coating[1,2,3,4,6,7,8,9] Application Rate kg/m^2	(lb/yd^2)	Type of Emission
Finishing Operation						
- 3 Print stations	0.91	(60)	3600	0.016	(0.030)	VOC
- 6 Print stations	0.91	(60)	3600	0.076	(0.144)	VOC

The industry makes every effort to reduce the amount of solvent retained in the finished product to a level less than can be detected by analytical methods. Therefore, in order to develop a solvent balance around each model plant it is assumed that none of the solvent is retained in the product so that all of the solvent applied with the finishing coatings becomes VOC emissions.

The oven on each rotogravure print line in the model plant is designed to operate at 25 percent of the lower explosive limit (LEL) (3925 ppmv) during normal coating operations.[1,6] Some ovens in the FVC&P industry have been designed and equipped to operate at higher LEL (up to 40 percent). However, these higher LEL levels are not yet fully operational.[5]

Using these parameters and assumptions, VOC emission rates can be calculated for each of the five model plants. Table 6-3 contains the results of these calculations.

6.1.1.1 Land and Utility Requirements. Table 6-4 lists the land and utility requirements for the model plants. The land requirements were estimated from observations of existing plant sites.

The utilities for the model plants consist of electricity for motors and natural gas for oven heat. Electric motors are used on winders and rewinders, print rolls, recirculation fans and exhaust fans. The electrical requirements are estimated at 0.04 kWh per square meter of production (0.045 hph per square yard of product).

The ovens are assumed to be heated with direct-fired natural gas furnaces. The fuel requirements are estimated at 110 J/hr per dscm/hr of oven air(250 Btu/hr per SCFM).

6.2 REGULATORY ALTERNATIVES

Three regulatory alternatives are investigated. Regulatory Alternative I represents baseline control which is the level of control that would probably result if the NSPS were not promulgated. Regulatory Alternative II represents the first level of NSPS control being considered. Regulatory Alternative III represents the second level of NSPS control being considered, a level of control achievable through the optimum capture of emissions and control with a carbon adsorption system.

TABLE 6-3. MODEL PLANT PARAMETERS

Model Plant	Number of Lines	Web width m (inches)	Number of Print Stations	Line Speed m/s (ypm)	Ink Application Rate Per line, kg/m^2 (lb/yd^2)	Uncontrolled VOC Emissions kg/hr (lb/hr)	Uncontrolled VOC Emissions Mg/yr[a] (ton/yr)
A	1	1.5 (60)	3	0.91 (60)	0.016 (0.030)	77 (170)	280 (310)
B	1	1.5 (60)	6	0.91 (60)	0.076 (0.144)	370 (820)	1300 (1480)
C	1	0.76 (30)	6	0.91 (60)	0.076 (0.144)	190 (410)	650 (740)
D	6	1.5 (60)	18[b]	0.91 (60)	0.016 (0.030)	470 (1030)	1700 (1850)
E	6	1.5 (60)	36[c]	0.91 (60)	0.076 (0.144)	2230 (4920)	8000 (8860)

[a] Based on an operating factor of 3600 hr/yr.

[b] Three stations per line.

[c] Six stations per line.

TABLE 6-4. ANNUAL PRODUCTION, LAND, AND UTILITY REQUIREMENTS (WITHOUT CONTROL DEVICES)

Model Plant	Annual Production	Land Requirements[1,5,6,10]		Annual Utilities	
				Electricity[1,5,6,10]	Fuel[1,5,6,7,10]
	m^2 (yd^2)	m^2	(ft^2)	KWh (hph)	J (BTU)
A	1.8×10^7 (21.6×10^6)	190	(2000)	0.73×10^6 (0.98×10^6)	4.7×10^{12} (0.45×10^{10})
B	1.8×10^7 (21.6×10^6)	190	(2000)	0.73×10^6 $(0.98 \times 10^6$	24×10^{12} (2.3×10^{10})
C	0.9×10^7 (10.8×10^6)	120	(1300)	0.36×10^6 (0.48×10^6)	12×10^{12} (1.1×10^{10})
D	11×10^7 (130×10^6)	1400	(15000)	4.4×10^6 (5.9×10^6)	28×10^{12} (2.7×10^{10})
E	11×10^7 (130×10^6)	1400	(15000)	4.4×10^6 (5.9×10^6)	130×10^{12} $12 \times 10^{10})$

Fixed-bed carbon adsorption systems are used as the VOC emission control devices in the model plants. Other control devices, such as incinerators, are available, however, fixed-bed carbon adsorption systems currently are used almost exclusively in the industry. This may be the result of increasing incinerator fuel costs and rising raw material solvent costs.

6.2.1 Regulatory Alternative I

As discussed in Chapter 3, the baseline control level for VOC emissions from the finishing operations is based on the graphic arts CTG which calls for 65 percent overall control. This 65 percent level represents a system which captures 70 percent of the total solvent from the FVC&P finishing operation and recovers or destroys 95 percent of those emissions.

6.2.2 Regulatory Alternative II

As also discussed in Chapter 3, the moderate control level for VOC emissions from the finishing operations is based on the rotogravure CTG which calls for 75 percent overall control. The moderate control level for VOC emissions may be achieved by capturing 80 percent of the solvent supplied at the presses and then controlling those captured emissions with a 95 percent efficient control device.

6.2.3 Regulatory Alternative III

For this alternative, optimum capture and control of oven exhaust gases and fugitive VOC emissions around the coating area of the printing devices are required. This is intended to correspond to 95 percent adsorber efficiency and 90 percent capture of the solvent emitted from the finishing operation resulting in 85 percent overall control. This may be accomplished by a system of ducts to capture and control all oven exhausts and one or both of the following plans:

- A system of fugitive vapor capture vents that capture emissions from the printing heads and the wet web as it travels into and out of the equipment, and duct these emissions to a carbon adsorber, or

A partial or total enclosure of the finishing line and the venting of the captured emissions to the carbon adsorber.

No additional dilution of the solvent laden air to the carbon adsorber due to the fugitive capture system is considered. This may be accomplished by drawing oven makeup air from around the printing line where fugitive vapors are generated.

6.2.4 Controlled Model Plant Parameters

The three regulatory alternatives were applied to each model plant. Table 6-5 contains a summary of the regulatory alternatives as they apply to the model plants. Cases A-1, B-1, C-1, D-1, and E-1 use the baseline control level for the finishing operations. Cases A-2, B-2, C-2, D-2, and E-2 use the moderate control level. Cases A-3, B-3, C-3, D-3 and E-3 use the stringent control level.

Material balances are calculated for all control cases. The results of these calculations and control device parameters are shown in Table 6-6. The control case numbers relate to the controlled model plants listed in Table 6-5.

6.2.4.1 Land and Utility Requirements for Model Plant Control Systems. Table 6-7 gives the land and utility requirements for the model plant control systems. Land requirements were estimated from observations of existing carbon adsorption, solvent recovery systems in industry.

The utilities for the control systems consist of cooling water for steam condensation, electricity for adsorber inlet fans and various pumps in the solvent recovery system, steam for desorbtion and for distillation columns, and carbon replacement. Cooling water requirements were estimated at 0.1 m^3 per 100 kg steam (12 gal per 100 lbs. steam). The major electricity user is the adsorber fan, therefore, the electrical requirements are based on airflow and estimated at 2.4 kWh/hr per dscm/h of adsorber inlet flow(8 hph/hr per 1000 SCFM). Steam requirements were estimated at 4.9 kg steam/kg recovered solvent. Carbon requirements were estimated using vendor data. The approximate ratio of carbon to solvent laden air is 3.2 Mg per 10,000 dscm/hr (6 tons per 10,000 SCFM).

TABLE 6-5. SUMMARY OF REGULATORY ALTERNATIVES

	Finishing Operation	
Case	Regulatory Alternative	VOC Control Level
A-1	I	65% overall control
B-1		
C-1		
D-1		
E-1		
A-2	II	75% overall control
B-2		
C-2		
D-2		
E-2		
A-3	III	85% overall control
B-3		
C-3		
D-3		
E-3		

TABLE 6-6. CONTROL OPTION PARAMETERS - FINISHING OPERATION

Model Plant	Case No.	Number of Lines	Number of Print Stations	Regulatory Alternatives	Number of Carbon Adsorption Systems	VOC Emissions				Stack Emissions		Carbon Adsorption System Operating Data					
						Uncontrolled		Controlled				Temp In		Temp Out		P	
						Kg/hr	(lb/hr)	kg/hr	(lb/hr)	dscm/sec	(SCFM)	°K	(°F)	°K	(°F)	Pa	(in. of H_2O)
A	A-1	1	3	I	1	77	(170)	27	(60)	0.93	(2200)	310	(95)	310	(95)	4000	(16)
	A-2			II				20	(43)	1.1	(2600)	310	(95)	310	(95)	4000	(16)
	A-3			III				12	(26)	1.3	(3000)	310	(95)	310	(95)	4000	(16)
B	B-1	1	6	I	1	370	(820)	130	(290)	4.8	(11000)	310	(95)	310	(95)	5000	(20)
	B-2			II				95	(210)	5.7	(13000)	310	(95)	310	(95)	5000	(20)
	B-3			III				54	(120)	6.6	(15000)	310	(95)	310	(95)	5000	(20)
C	C-1	1	6	I	1	190	(410)	65	(140)	2.4	(5400)	310	(95)	(310)	(95)	4500	(18)
	C-2			II				45	(100)	2.8	(6300)	310	(95)	(310)	(95)	4500	(18)
	C-3			III				28	(62)	3.2	(7200)	310	(95)	(310)	(95)	4500	(18)
D	D-1	6	18[a]	I	1	470	(1030)	160	(360)	6.1	(14000)	310	(95)	310	(95)	5000	(20)
	D-2			II				110	(250)	7.0	(16000)	310	(95)	310	(95)	5000	(20)
	D-3			III				68	(150)	7.9	(18000)	310	(95)	310	(95)	5000	(20)
E	E-1	6	36[b]	I	1	2230	(4920)	780	(1720)	28	(65000)	310	(95)	310	(95)	5500	(22)
	E-2			II				560	(1230)	33	(76000)	310	(95)	310	(95)	5500	(22)
	E-3			III				140	(740)	36	(83000)	310	(95)	310	(95)	5500	(22)

[a] Three stations per line.

[b] Six stations per line.

TABLE 6-7. LAND AND UTILITY REQUIREMENTS FOR MODEL PLANT CONTROL SYSTEMS

Case No.	Cooling Water [1,5,6] m^3/hr[a]	Cooling Water [1,5,6] (gal/hr)[a]	Electricity kwh/hr	Electricity (hph/hr)	Steam[1,5,6] kg/hr	Steam[1,5,6] (lb/hr)	Replacement[11] Carbon[b] Mg	Replacement[11] Carbon[b] Tons	Land Requirements[c] m^2	Land Requirements[c] ft^2
A-1	0.25	(65)	14	(19)	250	(540)	1.3	(1.4)	290	(3,000)
A-2	0.28	(74)	16	(21)	280	(620)	1.5	(1.6)	290	(3,000)
A-3	0.32	(85)	19	(25)	320	(710)	1.6	(1.8)	290	(3,000)
B-1	1.2	(310)	69	(93)	1200	(2,600)	6.2	(6.8)	480	(5,000)
B-2	1.4	(360)	82	(110)	1400	(3,000)	7.1	(7.8)	480	(5,000)
B-3	1.6	(410)	95	(130)	1500	(3,400)	8.1	(8.9)	480	(5,000)
C-1	0.61	(160)	34	(46)	590	(1,300)	3.1	(3.4)	300	(3,200)
C-2	0.68	(180)	40	(54)	680	(1,500)	3.5	(3.9)	300	(3,200)
C-3	0.77	(200)	45	(60)	770	(1,700)	4.0	(4.4)	300	(3,200)
D-1	1.5	(400)	88	(120)	1500	(3,300)	7.7	(8.5)	1900	(20,000)
D-2	1.7	(460)	100	(130)	1700	(3,800)	8.9	(9.8)	1900	(20,000)
D-3	2.0	(520)	110	(150)	2000	(4,300)	10	(11)	1900	(20,000)
E-1	7.2	(1900)	410	(550)	7300	(16,000)	37	(41)	2900	(30,000)
E-2	8.3	(2200)	480	(640)	8200	(18,000)	43	(47)	2900	(30,000)
E-3	9.1	(2400)	520	(700)	9100	(20,000)	48	(53)	2900	(30,000)

[a] Cooling tower makeup.

[b] Carbon replacement will vary with process conditions but may be assumed to be every three years.

[c] Provides for carbon adsorption unit, cooling tower, solvent distillation, solvent drying, and recovered solvent storage tanks.

Moisture removal down to 0.5 weight percent water is necessary in the solvent recovery system. This is achieved through a complex distillation and dehydration system. The dehydration system requires approximately 60 kg of desiccant per m^3 of solvent (0.5 lb/gal.) in order to meet this requirement.

6.3 REFERENCES

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7. ENVIRONMENTAL AND ENERGY IMPACTS

The major environmental problem in the flexible vinyl coating and printing (FVC&P) industry is the emission of large amounts of volatile organic compounds (VOC). As discussed in Chapter 3, the VOC emissions result from the evaporation of organic solvent during the finishing operations of a FVC&P line.

Each finishing operation contains several printing stations, a topcoat station, and may include a precoater. The drying ovens used to remove the solvent and fuse the vinyl resins or inks onto the vinyl surface of the web, are the largest single source of VOC emissions in the plant production process. Fugitive VOC are emitted from around the coat/print stations and from the exposed wet web as it enters the drying oven. Small amounts of VOC emissions also occur during solvent handling and coatings formulation activities. In an uncontrolled plant the entire amount of solvent is vented to the atmosphere.

In this chapter the air, water, and solid waste pollution impacts, as well as energy impacts associated with the regulatory alternatives described in Chapter 6 are examined. These impacts are examined for individual model plants and for the United States as a whole. Basically the regulatory alternatives can be summarized as follows:

- Regulatory Alternative I (baseline control) - This alternative represents the control level recommended by EPA's Control Techniques Guidelines document for flexible packaging rotogravure operations (65 percent overall control).
- Regulatory Alternative II - This alternative represents the first level of NSPS control being considered. An overall VOC emission reduction of 75 percent would be achieved.

- Regulatory Alternative III - This alternative represents the second level of NSPS control being considered. This control level applies the best technological system of continuous VOC emission reduction for the flexible vinyl printing industry. The level of overall VOC reduction would be 85 percent.

Because of the reasons stated in Chapter 6 carbon adsorption systems are used in all regulatory alternatives as the means for controlling VOC emissions from the FVC&P industry. The environmental and energy analysis will, therefore, concentrate on the impacts resulting from the use of carbon adsorption solvent recovery systems.

7.1 AIR POLLUTION IMPACTS

7.1.1 Primary Air Pollution Impacts

Emissions estimates discussed in Chapter 3 indicate that about 21,600 megagrams (23,800 tons) of solvent should have been emitted to the atmosphere by existing controlled flexible vinyl coating and printing lines in 1980. The total potential emissions by existing FVC&P finishing lines for this year were about 61,700 megagrams (68,000 tons). The estimated emissions for 1980 assume that existing FVC&P lines are controlled to the recommended specialty gravure CTG limit of 65 percent overall reduction of VOC emissions. This section will compare the impacts of each regulatory alternative on national VOC emissions through the year 1987. The emissions of typical FVC&P finishing lines to be built through 1987 will also be characterized. These emission estimates are calculated based on predicted industry growth for the first five years that the regulatory alternative may be in effect.

Table 7-1 illustrates the estimated national VOC emissions from new, modified, or reconstructed FVC&P finishing lines from 1983 to 1987. The emissions resulting from Alternative I control (65 percent overall reduction), Alternative II control (75 percent overall reduction), and Alternative III control (85 percent overall reduction) are shown. By 1987 new, modified, or reconstructed FVC&P plants would have the potential to emit approximately 4100 megagrams (4500 tons) per year of uncontrolled

TABLE 7-1. ESTIMATED NATIONAL VOC EMISSIONS FROM NEW FLEXIBLE VINYL PRINTING LINES

Year	Potential Uncontrolled Emissions, Mg/yr	(Tons/yr)	Level of Controlled VOC Emissions Mg/yr (Ton/yr) Regulatory Alternative I		Regulatory Alternative II		Regulatory Alternative III		Incremental Impact on Baseline, Mg/yr (Ton/yr) Alt. I-Alt. II		Alt. I-Alt. III	
1983	820	(900)	290	(320)	200	(220)	120	(130)	90	(100)	170	(190)
1984	1600	(1800)	570	(630)	410	(450)	250	(270)	160	(180)	320	(360)
1985	2400	(2700)	860	(950)	610	(670)	370	(410)	250	(280)	490	(540)
1986	3300	(3600)	1100	(1200)	820	(900)	490	(540)	280	(300)	610	(660)
1987	4100	(4500)	1400	(1600)	1000	(1100)	610	(670)	400	(500)	790	(900)

*As discussed in Chapter 9, p. 9-21, during the period 1983 to 1987, 6 new plants with an annual output of 9 million square meters (10.8 million sq yd) will be required. That estimate is the basis for this table.

VOC. State SIP regulations at the Regulatory Alternative I level (65 percent control) would lower emissions of VOC to 1400 megagrams (1500 tons) per year. Regulatory Alternative II would further reduce emissions from new plants to 1000 megagrams (1100 tons) per year. The strictest level of proposed NSPS control, Alternative III, would reduce VOC emissions in 1987 to 610 megagrams (670 tons) per year. The incremental impact of Alternative II over the baseline control case (Alternative I) would be to reduce national VOC emissions from FVC&P finishing operations by an additional 30 percent in 1987. In 1987, Alternative III would reduce national VOC emissions from FVC&P finishing operations by 57 percent more than that achievable under Alternative I.

Similar incremental impacts occur when the regulatory alternatives are applied to the individual model plants developed in Chapter 6. Table 7-2 illustrates the results of such an application. Based on an analysis of FVC&P industry needs up to 1987, a plant which is somewhat larger than model plant C seems to be the most likely type to be built. Model plant C, controlled to the Alternative II level, would emit about 170 megagrams (190 tons) of solvent a year. Model plant C, controlled to the Alternative III level, would emit 100 megagrams (110 tons) of solvent per year. These emissions are 70 and 140 megagrams (70 and 150 tons) less respectively, than that expected from a comparable plant controlled to the Alternative I baseline level.

The primary impact of a VOC emissions reduction from this industry is a potential decline in ambient air organics levels and thus a reduction in ozone and photochemical smog formation. The major cause of smog is a photochemical reaction which starts with hydrocarbons and other organics in the atmosphere and produces a cloud of irritating chemicals. The VOC emitted from the FVC&P industry can, therefore, play an active part in the formation of oxygenated organic aerosols (photochemical smog). However, as an air pollution impact, the toxicity of the organic solvent component vapors is generally less important than the toxicity of their reaction products.

TABLE 7-2. AIR EMISSION IMPACTS OF THE REGULATORY ALTERNATIVES ON THE MODEL PLANTS*

Model Plants (line width, No. print stations)	Uncontrolled VOC Emissions, Mg/yr	(Kg/hr)	Controlled VOC Emissions, Mg/yr (kg/hr)					
			Regulatory Alternative I		Regulatory Alternative II		Regulatory Alternative III	
A (1.5m, 3)	280	(80)	100	(30)	70	(20)	40	(10)
B (1.5m, 6)	1300	(370)	460	(130)	330	(90)	200	(60)
C (0.76m, 6)	680	(190)	240	(70)	170	(50)	100	(30)
D (1.5m, 18)	1700	(470)	600	(170)	430	(120)	260	(70)
E (1.5m, 36)	8000	(2200)	2800	(780)	2000	(560)	1200	(340)

*Based on the model plants developed in Chapter 6 using Model Plant C as an example:

The ink or coating application rate varies from 0.005 to 0.09 kg per square meter (0.001 to 0.17 lb per sq yd).[1,2,6] If the solvent of the coating content was 85%, the VOC would range from 0.0004 to 0.076 kg per square meter (0.0008 to 0.144 pounds per yd^2). There is some indication that new plants may achieve desired results with less solvent. Therefore, using 0.139 pounds per yd^2 (See note a, Table 3-3):

$$\frac{10.8\ yd^2 \times 10^6 \times 0.139}{2000} = 750 \text{ tons/yr.} \quad 750 \times 0.907 = 680 \text{ Mg/yr - potential uncontrolled emissions.}$$

The transformation of organic vapors to aerosols involves reactions between the organics, ozone, ultraviolet irradiation (sunlight), and nitrogen oxides (NO_x). The organics react to produce additional ozone and oxygenated compounds which form aerosols by either nucleation or condensation.[3] The nitrogen oxide levels required for photochemical smog formation are generally only encountered in industrial or urban areas. This is very pertinent to the study of the FVC&P industry since the majority of the industry's plants are located in the heavily industrialized north central and northeastern regions of the country.

7.1.2 Secondary Air Pollution Impacts

Secondary environmental impacts are defined as those impacts which result from the addition of pollution control equipment. In the case of the FVC&P industry, solvent emissions control systems are sources of potential secondary emissions.

The major secondary air pollution impacts of carbon adsorption systems are the fuel combustion emissions from the boiler used to produce steam. The steam is used to strip the carbon bed of adsorbed VOC at a ratio of 4 kilograms of steam per kilogram recovered solvent. Steam is also produced (1 kilogram per kilogram recovered solvent) for use in the distillation column used to refine the recovered solvent. Assuming the model plants use number two fuel oil in their boilers, estimates can be made on the relative levels of secondary emissions resulting from controls. Hydrocarbon emissions would be negligible, only about 0.000051 kilograms per kilogram (0.000051 lb per lb) recovered solvent, assuming the boiler was well operated and maintained. For particulates the emission rate is approximately 0.0125 kilograms per kilogram recovered solvent (0.0125 lb per lb recovered solvent).[4,5] The emission rates of sulfur oxides (SO_x) are dependent on the level of sulfur in the fuel oil. For a 0.3 weight percent sulfur fuel oil, 0.0027 kilograms of SO_2 per kilogram recovered solvent (0.0027 lb per lb recovered solvent) are emitted. The magnitude of the secondary pollutants generated by the operation of the control system is much smaller than the magnitude of the solvent emissions being recovered.

An NSPS for industrial boilers, currently being developed by EPA, will further reduce the impact of these secondary emissions by requiring the control of NO_x, SO_x, and other boiler emissions.

Secondary air pollutants are also formed as a result of electrical power generation. The electrical power is required to drive solvent-laden air fans, cooling tower pumps and fans, boiler pumps and fans, and all emission controls instrumentation. The quantity and type of pollution produced would vary considerably depending on the geographical location and the fuel resources available. Prediction of the secondary environmental impact associated with electrical power generation is beyond the scope of this study. Electrical consumption is not large and not considered to be a significant impact. Since the power plants are separate offsite facilities, which are already governed by emission regulations, this source was not considered.

Cooling towers could be an additional source of secondary air pollution with a carbon adsorption unit. Particulates in cooling towers result from dissolved solids emitted to the atmosphere by cooling tower drift. This particulate emission is generally not a problem in cooling towers of the size found on carbon adsorption units in the FVC&P industry.

7.2 WATER POLLUTION IMPACTS

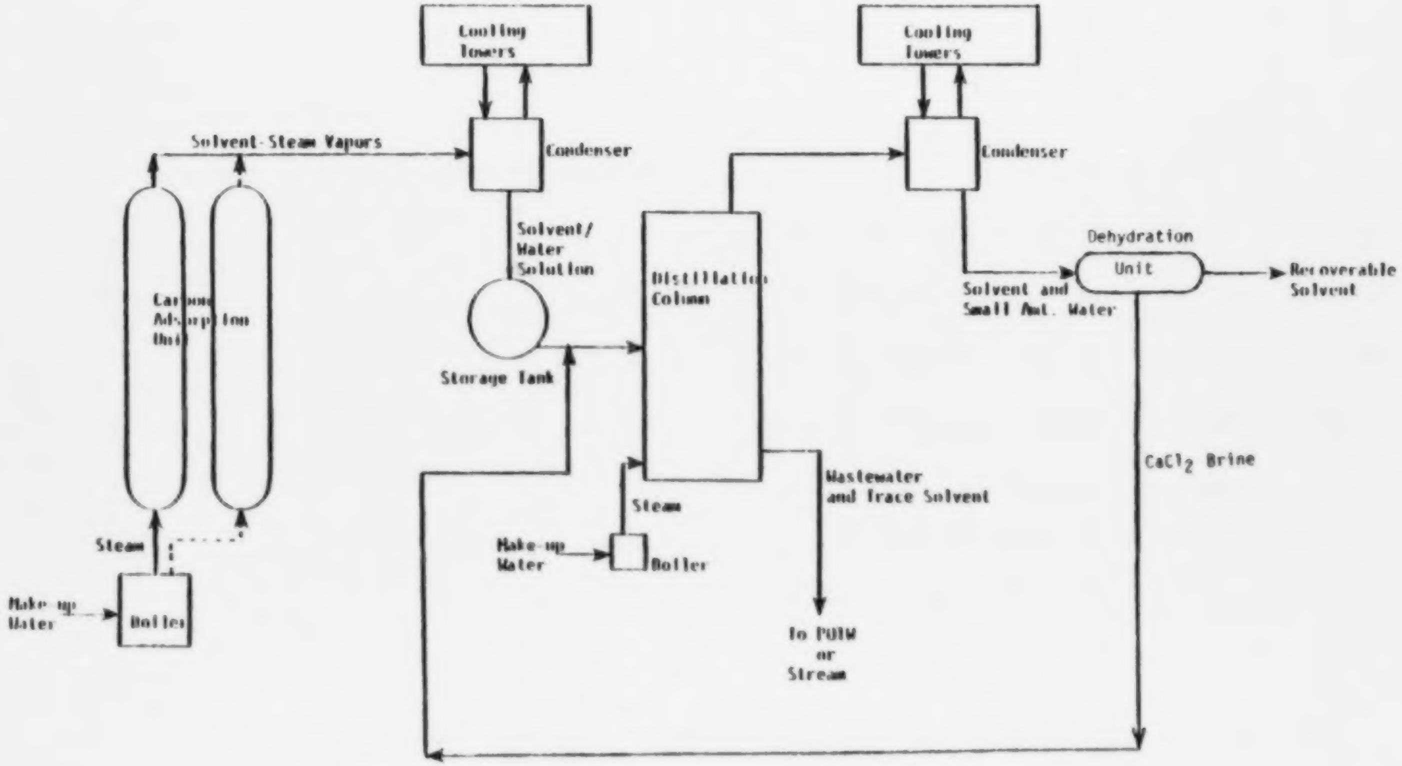
The only potential wastewater pollution from a controlled FVC&P plant arises from the use of the carbon adsorption emission reduction system. Dissolved solvent in the condensate from the carbon adsorption system represents the primary potential water pollutant.

Carbon adsorption devices use steam to strip adsorbed solvent from the carbon beds. During the stripping operation, the solvent-steam vapors are fed to a condenser. The condensed solvent-water solution from the condenser is then sent to a storage tank after pH adjustment. Little separation of solvent and water takes place in the storage tank because of the high miscibility of ketone solvents in water.

From storage the solvent-water solution is sent to a distillation column. The majority of solvent is removed from the solution during distillation. After distillation the vaporized solvent (which contains a small amount of water) is sent to a second condensation step. Following the second condensation step, a solution of solvent and a small amount of water is sent to a dehydration unit. In the dehydration unit calcium chloride is used to dry the solvent/water mixture. The spent calcium chloride brine is sent back through the distillation column and eventually is discharged to a publically owned treatment works (POTW) or the environment. A schematic view of the water cycle in a controlled FVC&P model plant is shown in Figure 7-1.

The wastewater discharges for the FVC&P model plants were estimated based on the total quantity of incoming make-up water used to produce steam for the carbon adsorption/distillation system. The wastewater discharges associated with the model plants of Chapter 6 are given in Table 7-3. A typical plant to be built in this industry would have an annual wastewater discharge, attributable to VOC control, of 2.6 million liters (690,000 gallons) under Regulatory Alternative II and 3 million liters (780,000 gallons) under Alternative III.

The national wastewater discharges resulting from the implementation of emissions controls on new FVC&P plants are presented in Table 7-4. In 1987 plants controlled to the Alternative I level would discharge approximately 13.2 million liters (3.5 million gallons) of wastewater per year. An increased emissions reduction to the Alternative II level would increase wastewater discharges to about 15.6 million liters (4.1 million gallons) per year. This represents a 2.4 million liter (600,000 gallons) increase in wastewater discharges to achieve a 400 megagrams (440 tons) VOC emissions reduction. Control to the Alternative III level in 1987 would increase potential wastewater discharges to 18 million liters (4.8 million gallons) per year from new FVC&P finishing facilities. Compared to the baseline case, Alternative III control would cause the discharge of 4.8 million liters (1.3 million gallons) more wastewater to achieve a national VOC emissions reduction of 790 megagrams (870 tons) from new FVC&P finishing lines.



Cooling Towers
Condenser
Cooling Towers
Condenser
Solvent-Steam Vapors
Solvent/ Water Solution
Carbon Adsorption Unit
Storage Tank
Distillation Column
Dehydration Unit
Recoverable Solvent
Solvent and Small Amt. Water
CaCl2 Brine
Wastewater and Trace Solvent
To POTW or Stream
Steam
Make-up Water
Boiler
Steam
Make-up Water
Boiler

FIGURE 7-1. SCHEMATIC OF THE WATER CYCLE IN A FVC&P PLANT SOLVENT RECOVERY SYSTEM

TABLE 7-3. WASTEWATER DISCHARGE IMPACTS OF THE REGULATORY ALTERNATIVES ON THE MODEL PLANTS*

Model Plants (line width, No. Print Stations)	Annual Wastewater Discharges, liters (gallons)		
	Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative III
A (1.5m, 3)	910,000 (240,000)	1,100,000 (290,000)	1,200,000 (330,000)
B (1.5m, 6)	4,200,000 (1,100,000)	5,300,000 (1,400,000)	6,100,000 (1,600,000)
C (0.76m, 6)	2,200,000 (590,000)	2,600,000 (690,000)	3,000,000 (780,000)
D (1.5m, 18)	5,700,000 (1,500,000)	6,400,000 (1,700,000)	7,600,000 (2,000,000)
E (1.5m, 36)	26,100,000 (6,900,000)	31,000,000 (8,200,000)	36,000,000 (9,500,000)

*Based on the model plants developed in Chapter 6.

TABLE 7-4. ESTIMATED NATIONAL WASTEWATER DISCHARGE IMPACTS FROM VOC CONTROL SYSTEMS

Year	Annual Wastewater Discharge, liters (gallons)			Incremental Impact on Baseline, liters (gallons)	
	Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative III	Alt. I - Alt. II	Alt. I - Alt. III
1983	2,600,000 (700,000)	3,100,000 (820,000)	3,600,000 (950,000)	480,000 (120,000)	960,000 (250,000)
1984	5,300,000 (1,400,000)	6,200,000 (1,600,000)	7,200,000 (1,900,000)	960,000 (200,000)	1,900,000 (500,000)
1985	7,900,000 (2,100,000)	9,400,000 (2,500,000)	10,800,000 (2,900,000)	1,400,000 (400,000)	2,900,000 (800,000)
1986	10,600,000 (2,800,000)	12,500,000 (3,300,000)	14,400,000 (3,800,000)	1,900,000 (500,000)	3,800,000 (1,000,000)
1987	13,200,000 (3,500,000)	15,600,000 (4,100,000)	18,000,000 (4,800,000)	2,400,000 (600,000)	4,800,000 (1,300,000)

The amount of VOC being emitted in these national wastewater discharges would be relatively small. In 1987, under Regulatory Alternative I, the wastewater streams of VOC control systems, for new flexible vinyl finishing lines, would contain about 4.9 megagrams (5.4 tons) of VOC. Increasing the required control level to Alternative II would increase the quantity of VOC discharged in wastewater streams to 5.7 megagrams (6.3 tons) per year. Control to the Alternative III level would increase VOC released in the control system wastewater discharges to 6.5 megagrams (7.1 tons) per year. These VOC impacts represent worst case situations. These impacts were based on the assumptions that all new facilities would use a solvent recovery control system and all wastewater is discharged with no process recycle and reuse. Table 7-5 fully illustrates the impacts of VOC in the control system wastewater discharges.

The environmental impact on natural water systems from these wastewater discharges would be minimal because: (1) the total volume of annual wastewater discharge is small and (2) the discharge contains only alkaline dehydration chemicals (calcium chloride or sodium hydroxide) and small amounts of organic solvent. Plants currently operating in this industry with carbon adsorption/distillation systems are permitted to discharge wastewater streams attributable to VOC control to POTW without any penalties or surcharges.

7.3 SOLID WASTE IMPACTS

The only expected solid wastes from VOC emissions control systems come from the carbon adsorption devices. The activated carbon in these units gradually degrades during normal operation. The adsorption efficiency of the carbon eventually drops to such a level that replacement is necessary. This replacement creates a solid waste load for the plant. The quantities of waste carbon generated annually by the various model FVC&P plants are given in Table 7-6. Waste carbon from the largest plant controlled to the highest level would equal 48 megagrams per year (53 tons/yr).

TABLE 7-5. ESTIMATED NATIONAL VOC LOADING OF VOC CONTROL SYSTEM WASTEWATER STREAMS

Year	Annual VOC Emissions, Mg (Tons)						Incremental Impact on Baseline, Mg (Tons)			
	Regulatory Alternative I		Regulatory Alternative II		Regulatory Alternative III		Alt. I - Alt. II		Alt. I - Alt. III	
1983	0.89	(0.98)	1.0	(1.1)	1.2	(1.3)	0.15	(0.16)	0.31	(0.32)
1984	1.9	(2.1)	2.2	(2.4)	2.5	(2.8)	0.27	(0.30)	0.60	(0.70)
1985	2.9	(3.2)	3.3	(3.7)	3.8	(4.2)	0.40	(0.50)	0.90	(1.0)
1986	3.9	(4.3)	4.5	(5.0)	5.1	(5.7)	0.60	(0.71)	1.2	(1.4)
1987	4.9	(5.4)	5.7	(6.3)	6.5	(7.1)	0.80	(0.90)	1.6	(1.7)

TABLE 7-6. SOLID WASTE IMPACTS OF THE REGULATORY ALTERNATIVES ON THE MODEL PLANTS*

Model Plants (line width, No. Print Stations)	Annual Solid Waste Impacts, Mg(Tons)					
	Regulatory Alternative I		Regulatory Alternative II		Regulatory Alternative III	
A (1.5m, 3)	1.3	(1.4)	1.5	(1.6)	1.6	(1.8)
B (1.5m, 6)	6.2	(6.8)	7.1	(7.8)	8.1	(8.9)
C (0.76m, 6)	3.1	(3.4)	3.5	(3.9)	4.0	(4.4)
D (1.5m, 18)	7.7	(8.5)	8.9	(9.8)	10	(11)
E (1.5m, 36)	37	(41)	43	(47)	48	(53)

*Based on the model plants developed in Chapter 6.

This disposal of the waste carbon material creates a potential secondary environmental impact. Three procedures are available for handling waste carbon that reduce the potential of adverse environmental impacts. The three involve: a) properly landfilling the carbon, b) recycling the carbon by reactivation, and c) using the carbon as a fuel source.

The implementation of the landfill method will be simple and efficient because the technology for the operation is considered common practice. No environmental problems should occur provided the landfill site has been properly constructed. If the site is not secured by a lining of some type (either natural or artificial), possible soil leaching could occur. The leachate may contain traces of organics which have been left on the carbon as residues. Transmission of this leachate into ground and surface waters would represent a potential environmental impact.

The second treatment procedure for the waste carbon involves recycling the carbon to its manufacturer. The manufacturer can process the waste carbon and reactivate it for reuse in carbon adsorption units. At least one manufacturer is using this method.[2]

The third disposal method involves selling the waste carbon as a fuel. The physical and chemical structure of the carbon in combination with the hydrocarbon residues make the wastes a fuel product similar to other solid fuels such as coal. Potential users of this fuel include industrial and small utility boilers. Since activated carbon generally contains very little sulfur, furnace SO_2 emissions resulting from combustion would be negligible. Particulate and NO_x emissions from the burning of activated carbon would be comparable to those of coal-fired operations. However, the use of this disposal method would be limited because of the small quantities of carbon generated by plants in this industry.

Nationwide solid waste resulting from the VOC emission control systems of FVC&P plants would not pose adverse environmental impacts. Estimates of national solid waste resulting from new, controlled FVC&P

plants are given in Table 7-7. In 1987 plants controlled to the Alternative I level would be generating approximately 19 megagrams per year (21 tons/yr) of waste carbon. The same plants controlled to the Alternative II level would generate about 21 megagrams per year (23 tons/yr) of carbon waste. The 3 megagrams of increased carbon waste is a trade-off for an increase in overall VOC emissions reduction of 400 megagrams per year (440 tons/yr). Plants controlled to the Alternative III level would generate 24 megagrams (26 tons) per year of waste carbon, or 5 megagrams per year more than facilities under Alternative I control. The additional solid waste generation results in increased VOC emission reductions from new FVC&P facilities of 790 megagrams (870 tons) per year in 1987.

7.4 ENERGY IMPACT

The air emissions control equipment for the FVC&P industry, utilizes electrical energy and steam. The electrical energy is required to operate solvent-laden air fans, cooling tower pumps and fans, boiler support systems, and all control system instrumentation. Fossil fuel, typically fuel oil, is combusted in the solvent recovery system's boilers to produce steam for carbon adsorption and distillation. For the energy impact analysis an 80 percent thermal efficiency was assumed for the fuel oil usage.

The electricity consumptions calculated for each model plant and regulatory alternative case are presented in Table 7-8. In the model plant cases an average of 15 percent more electricity is required to reduce overall VOC emissions from the Alternative I to the Alternative II control level. A typical new FVC&P finishing line, under Alternative II control, would require about 840 GJ (230,000 kwh) per year of electrical energy. Control to the Alternative III level would require approximately 30 percent more electrical energy than Alternative I control. In 1987 a new finishing line under Alternative III control would require about 970 GJ (270,000 kwh) per year of electrical energy.

The gross nationwide consumption of electricity by new FVC&P finishing lines, for VOC control purposes, is shown in Table 7-9. In 1987 new

TABLE 7-7. ESTIMATED NATIONAL SOLID WASTE IMPACTS FROM VOC CONTROL SYSTEMS

Year	Annual Solid Waste Impact, Mg (Tons) Regulatory Alternative I	Annual Solid Waste Impact, Mg (Tons) Regulatory Alternative II	Annual Solid Waste Impact, Mg (Tons) Regulatory Alternative III	Incremental Impact on Baseline Mg (Tons) Alt. I-Alt. II	Incremental Impact on Baseline Mg (Tons) Alt. I-Alt. III
1983	3.7 (4.1)	4.2 (4.6)	4.8 (5.3)	0.5 (0.5)	1.1 (1.2)
1984	7.4 (8.2)	8.4 (9.3)	9.6 (10.6)	1.0 (1.1)	2.2 (2.4)
1985	11 (12)	13 (14)	14 (16)	1.5 (1.6)	3.2 (3.6)
1986	15 (16)	17 (19)	19 (21)	1.9 (2.1)	4.3 (4.8)
1987	19 (21)	21 (23)	24 (26)	2.4 (2.7)	5.4 (6.0)

TABLE 7-8. ELECTRICITY IMPACTS OF THE REGULATORY ALTERNATIVES ON THE MODEL PLANTS

Model Plants (line width, No. Print Stations	Annual Electricity Consumption, GJ (kwh)					
	Regulatory Alternative I		Regulatory Alternative II		Regulatory Alternative III	
A (1.5m, 3)	300	(84,000)	350	(97,000)	420	(110,000)
B (1.5m, 6)	1500	(420,000)	1800	(500,000)	2000	(570,000)
C (0.76m, 6)	720	(200,000)	840	(230,000)	970	(270,000)
D (1.5m, 18)	2000	(530,000)	2200	(600,000)	2300	(670,000)
E (1.5m, 36)	9000	(2,500,000)	10,200	(2,800,000)	11,400	(3,200,000)

*Based on the model plants developed in Chapter 6.

TABLE 7-9. ESTIMATED NATIONAL ELECTRICITY IMPACTS FROM VOC CONTROL SYSTEMS

	Annual Electricity Consumption, GJ (kWh)			Incremental Impact on Baseline, GJ (kWh)	
Year	Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative III	Alt. I - Alt. II	Alt. I - Alt. III
1983	860 (240,000)	1000 (280,000)	1200 (320,000)	140 (40,000)	340 (80,000
1984	1700 (480,000)	2000 (560,000)	2300 (650,000)	300 (80,000)	600 (170,000)
1985	2600 (720,000)	3000 (840,000)	3500 (970,000)	400 (120,000)	900 (250,000)
1986	3500 (960,000)	4000 (1,100,000)	4700 (1,300,000)	500 (140,000)	1200 (340,000)
1987	4300(1,200,000)	5000 (1,400,000)	5800 (1,600,000)	700 (200,000)	1500 (400,000)

facilities controlled to the Alternative II level would consume 15 percent more electricity than facilities under Alternative I control. Alternative II control, in 1987, would require 5000 GJ (1,400,000 kwh) of electricity per year. Alternative III control in 1987 would require about 30 percent more electrical energy than if all new FVC&P finishing operations were controlled to the Alternative I level. Finishing lines under Alternative III control would use about 5800 GJ (1,600,000 kwh) of electricity for VOC control.

The fuel oil consumptions for the model plant and regulatory alternative cases of Chapter 6 are given in Table 7-10. A typical new FVC&P finishing line to be built within the next five years would require about 7,200 GJ (6.8 billion Btu) of fuel oil to meet the Alternative I emission control level. Approximately 1,100 additional GJ (1.0 billion Btu) of energy would be required to control the plant's VOC emissions to the Alternative II level. Control of new finishing lines to the Alternative III level would require 2,500 GJ (2.4 billion Btu) of fuel oil energy above the amount required for Alternative I control.

The estimated gross national fuel oil impacts resulting from VOC control systems are given in Table 7-11. Nationwide, in 1987, about 43,000 GJ (41 billion Btu) of fuel oil energy would be consumed by new FVC&P finishing lines controlled to the Alternative I level. An additional 7,000 GJ (6.0 billion Btu) of fuel oil would be required nationwide to raise the overall emission reduction being achieved by new FVC&P finishing lines to the Alternative II level. Control to the Alternative III level would raise fuel oil use by 15,000 GJ (14 billion Btu) above that required for Alternative I control.

Net national energy savings are possible in this industry when the energy value of the recovered solvent is considered. If all new FVC&P finishing lines built through 1987 were controlled to the level of Regulatory Alternative I, the gross national energy demand would be equal to about 48,000 GJ (45 billion Btu). The amount of solvent potentially recoverable under Alternative I control could be translated into about 83,000 GJ (78 billion Btu) of energy. The net energy impact

TABLE 7-10. FUEL OIL IMPACTS OF THE REGULATORY ALTERNATIVES ON THE MODEL PLANTS*

Model Plants (line width, No. Print Stations)	Annual Fuel Oil Consumption, GJ (billions of Btu)					
	Regulatory Alternative I		Regulatory Alternative II		Regulatory Alternative III	
A (1.5m, 3)	3,000	(2.8)	3,500	(3.3)	4,000	(3.8)
B (1.5m, 6)	14,000	(13)	16,000	(15)	18,000	(17)
C (0.76m, 6)	7,200	(6.8)	8,300	(7.9)	9,700	(9.2)
D (1.5m, 18)	18,000	(17)	21,000	(20)	24,000	(23)
E (1.5m, 36)	86,000	(82)	99,000	(94)	112,000	(110)

*Based on the model plants developed in Chapter 6.

TABLE 7-11. ESTIMATED NATIONAL FUEL OIL IMPACTS FROM VOC CONTROL SYSTEMS

	Annual Consumption of No. 2 Fuel Oil, GJ (billions of Btu)			Incremental Impact on Baseline, GJ (billions of Btu)	
Year	Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative III	Alt. I - Alt. II	Alt. I - Alt. III
1983	8,600 (8.2)	10,000 (9.4)	12,000 (11)	1,400 (1.2)	3,400 (2.8)
1984	17,000 (16)	20,000 (1.9)	23,000 (22)	3,000 (3.0)	6,000 (6.0)
1985	26,000 (25)	30,000(28)	35,000 (33)	4,000 (3.0)	9,000 (8.0)
1986	35,000 (33)	40,000(38)	47,000 (44)	5,000 (5.0)	12,000(11)
1987	43,000 (41)	50,000(47)	58,000 (55)	7,000 (6.0)	15,000(14)

in 1987, under Alternative I control, is an energy savings of 35,000 GJ (33 billion Btu).

Under Regulatory Alternative II control the gross national energy demand would approach 55,000 GJ (52 billion Btu) in 1987. Alternative II control would recover an energy equivalent of 95,000 GJ (90 billion Btu). The net energy impact under Alternative II control, in 1987, would be an energy savings of 40,000 GJ (38 billion Btu). The gross national energy demand under Alternative III control would equal approximately 64,000 GJ (61 billion Btu). The higher control efficiency of this alternative would yield a potential solvent recovery equivalent to 105,000 GJ (100 billion Btu) of energy. The net energy impact under Alternative III control, in 1987, would be an energy savings of 41,000 GJ (39 billion Btu).

The incremental energy savings of Alternative II compared to Alternative I would equal 5,000 GJ (5.0 billion Btu). Alternative III would have a potential energy savings of 6,000 GJ (6.0 billion Btu) when compared to Alternative I. Table 7-12 fully illustrates the potential net national energy impacts in the FVC&P industry. The favorable national energy impact is important because of the lessening supply and increasing cost of petroleum raw materials.

7.5 OTHER ENVIRONMENTAL IMPACTS

The impact of increased noise levels is not a significant problem within the emission control systems of the FVC&P industry. No noticeable increases in noise levels occur as a result of increasingly stricter regulatory alternatives. Motors and solvent-laden air fans are responsible for the majority of the noise in VOC control systems.

Other than the fuels required for steam and electricity generation, and the materials required for the construction of the system, there is no apparent irreversible or irretrievable commitment of resources associated with the construction or operation of the emission control systems. Essentially the VOC emission controls for this industry do not produce any significant air, water, or land pollution problems. The control and recovery of these solvent emissions is both energy efficient and economical.

TABLE 7-12. NET NATIONAL ENERGY IMPACTS OF VOC CONTROL, GJ (billions of Btu)

National Totals	Regulatory Alternative I	Regulatory Alternative II	Regulatory Alternative III	Incremental Impact on Baseline	
				Alt. I - Alt. II	Alt. I - Alt.III
Recovered Solvent	83,000 (78)	95,000 (90)	105,000 (100)	12,000 (12)	22,000 (22)
Energy Demand	48,000 (45)	55,000 (52)	64,000 (61)	7,000 (7)	16,000 (16)
Energy Savings	35,000 (33)	40,000 (38)	41,000 (39)	5,000 (5)	6,000 (6)

7.6 REFERENCES

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5. Devitt, T., P. Spaite, and L. Gibbs. (PEDCo Environmental) Background Study in Support of New Source Performance Standards for Industrial Boilers. (Prepared for U.S. Environmental Protection Agency.) Research Triangle Park, N.C. EPA Contract No. 68-02-2603. March 1979. p. 96.

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8. COSTS

The cost impacts of implementing the various regulatory alternatives are presented for each model plant in this chapter. Both process and control costs are presented, however, the emphasis is on the incremental control costs above an assumed baseline regulatory alternative. The bases for the cost analysis are presented in terms of the data sources, assumptions, and factors used in this analysis. These cost impacts will serve as inputs to the economic analysis in Chapter 9.

8.1 COST ANALYSIS OF REGULATORY ALTERNATIVES

Three regulatory alternatives are presented in Chapter 6. These alternatives call for an overall volatile organic compound (VOC) reduction of 65, 75, or 85 percent.

- Regulatory Alternative I, the baseline, is based on the Control Techniques Guideline (CTG) document for special products in the Graphic Arts industry.[1] This control alternative assumes no NSPS would be promulgated. Regulatory Alternative I is based on an overall VOC emission reduction of 65 percent. This 65 percent level represents a system which captures 70 percent of the total solvent from the FVC&P finishing operation and recovers or destroys 95 percent of those emissions.
- Regulatory Alternative II represents the first level of NSPS control being considered. This control level is based on an overall VOC emission reduction of 75 percent. The control system for Alternative II would capture 80 percent of the total solvent emitted from the finishing operation and then recover or destroy 95 percent of those emissions.
- Regulatory Alternative III represents the second level of NSPS control being considered. Alternative III is based on an overall VOC emission reduction of 85 percent. The 85 percent level represents a

system which captures 90 percent of the total solvent emitted from the finishing operation and then recovers or destroys 95 percent of those emissions.

Each regulatory alternative is applied to five model plants. A total of fifteen model plant cases result. Specific information about each model plant is presented in Chapter 6. A cost analysis is presented in this section for each model plant and corresponding emission control system. A discussion concerning modified or reconstructed facilities is also presented.

8.1.1 New Facilities

Table 8-1 outlines the five model plants that are examined in this cost analysis. The probable accuracy of the cost estimates presented in this section is ±30 percent. The results are to be used as a comparative basis to document the economics which may face a manufacturer if a regulation goes into effect. All costs for this study are expressed in mid-1980 dollars.

8.1.1.1 Installed Capital and Annualized Costs. Fixed-bed carbon adsorption systems are used as the VOC emission control devices in the model plants. Other control devices, such as incinerators, are available, however, fixed-bed carbon adsorption systems currently are used almost exclusively in the industry. The use of waterborne inks is another control option but no cost information is available from industry. There is little commercial use of waterborne inks in the FVC&P industry.

Presently, it is likely that incineration and waterborne inks prove to be more costly control options. With further development, waterborne inks may prove to be a less costly control option. If incineration or waterborne inks provide lower costs than carbon adsorbers, and are implemented by industry, this would not effect the conclusions of this study.

Table 8-2 lists the assumptions used in calculating the capital and operating costs of the model plants and their control systems. Some costs such as raw materials, utilities and labor are highly dependent on location. A detailed study of these variations will not be presented in this report.

TABLE 8-1. MODEL PLANTS

Model Plant	Web[2,3,4,5] Width m (inches)	Number of Print Lines	Number[2,3,4,5] of Print Stations	Ink[1,6] Formulation
A	1.5 (60)	1	3	5% solids
B	1.5 (60)	1	6	5% solids
C	0.76 (30)	1	6	5% solids
D	1.5 (60)	6	18[a]	5% solids
E	1.5 (60)	6	36[b]	5% solids

[a] Three print stations per print line

[b] Six print stations per print line

TABLE 8-2. BASES FOR ANNUALIZED COST ESTIMATES

Description	Unit Cost	Basis for Costs
Annualized costs for new installation	One Year	Commencing mid-June (1980)
Average model plant operating time	3600 hr/yr	60% of scheduled operating time
Average Carbon adsorption, solvent recovery system operating time	6000 hr/yr for adsorbers 3600 hr/yr for solvent recovery	
Direct Operating Costs		
Operating Labor		
Operator	\$10.00/hr	Reference 10
Supervisor	15% of operator labor	Reference 10
Maintenance	5% of installed capital	Reference 10
Raw Materials	0.52/sq.m (0.46/sq. yd)	Reference 6
	0.59 sq.m (0.49/sq. yd)	Reference 6
Carbon Replacement	\$2.53/kg (\$1.15/lb)	Reference 6
	Replace every three years	Reference 6
Utilities		
Steam	\$11.00/Mg (\$5.00/1000 lb)	Reference 6
Electricity	\$0.05/kWh	Reference 6
Water	\$0.26/m^3 (\$0.972/1000 gal)	Reference 6
Fuel	\$3.80/10^{3}J (\$4.00/10^{6}Btu)	Reference 6

TABLE 8-2. (CONTINUED)

Description	Unit Cost	Basis for Costs
Indirect Operating Costs		
Overhead	80% of labor	Reference 10
Taxes and Insurance	2% of installed capital	Reference 10
Administration	2% of installed capital	Reference 10
Capital Recovery Factor		
Finishing line	10.226% of installed capital	10% interest rate, 40 year lifetime[6]
Carbon adsorption	11.746% of installed capital	10% interest rate, 20 year lifetime[6]
Credits		
Solvent credit	\$0.704/kg(\$0.32/lb)	Recovered solvent for sale or reuse[12]

Finishing Line Costs

The installed capital costs for the finishing lines (without control equipment) are based on vendor[7] and industry sources. The installed capital cost of a 1.5 meter (60 inch), 3 station model plant printing line is estimated at 1 million dollars. The installed capital cost of a 1.5 meter (60 inch), 6 station model plant printing line is estimated at 1.8 million dollars. The installed capital cost for a 0.76 meter (30 inch), 6 station model plant print line is estimated at 1 million dollars. These model plant printing lines include the rotogravure presses and associated ovens, web winders and rewinders, ink tanks, pumps, LEL meters, steam piping, motors and starters, quality control inspection equipment, web speed control devices, ventilation equipment (such as fans and hoods to meet OSHA regulations), and housing structures. Annualized costs for the model plant print lines were developed using the assumptions presented in Table 8-2 and utility requirements presented in Table 6-4. The installed capital and annualized costs for the model plant finishing lines are presented in Table 8-3.

Control Equipment Costs

Several sources were investigated in the development of the control equipment installed capital costs: industry contacts, vendor quotes[8,9] and EPA reference manuals.[10,13] EPA reference manuals[10,13] were not adequate because complex distillation equipment must be used in this industry and these manuals did not contain costing information for this equipment. Vendor[8,9] information was often incomplete and did not reflect the installation costs for these systems. Equipment costs before installation were not available from industry sources because the control systems were installed and turned over to the plants as operational units. Therefore, the installed capital costs for the model plant control systems were estimated using industry cost data for installed control systems. Figure 8-1 is the cost curve used to estimate the installed capital costs of the model plant control systems. This cost curve was used to cost model plant control systems for all the Regulatory Alternatives.[14]

TABLE 8-3. INSTALLED CAPITAL AND ANNUALIZED COSTS FOR UNCONTROLLED MODEL PLANTS ($1980)

Model Plant	A	B	C	D	E
Production m^2/yr (yd^2/yr)	1.8×10^7 (21.6×10^6)	1.8×10^7 (21.6×10^6)	0.9×10^7 (10.8×10^6)	11×10^7 (130×10^6)	11×10^7 (130×10^6)
Installed Capital Cost	1,000,000	1,800,000	1,000,000	6,000,000	10,800,000
Direct Operating Costs					
Operating Labor					
Operator	240,000	300,000	240,000	1,320,000	1,680,000
Supervisor	36,000	45,000	36,000	138,000	252,000
Maintenance	50,000	90,000	50,000	300,000	540,000
Utilities					
Electricity	37,000	37,000	18,000	220,000	220,000
Fuel	18,000	92,000	44,000	110,000	480,000
Raw Materials	9,936,000	10,600,000	5,300,000	59,800,000	63,700,000
Indirect Operating Costs					
Overhead	241,000	312,000	241,000	1,334,000	1,762,000
Taxes and Insurance	20,000	36,000	20,000	120,000	216,000
Administration	20,000	36,000	20,000	120,000	216,000
Capital Recovery Cost	100,000	180,000	100,000	610,000	1,100,000
Total Annualized Cost	10,698,000	11,728,000	6,069,000	64,132,000	69,914,000
$/sq.m	0.59	0.65	0.67	0.58	0.64
($/sq.yd)	(0.50)	(0.54)	(0.56)	(0.49)	(0.54)

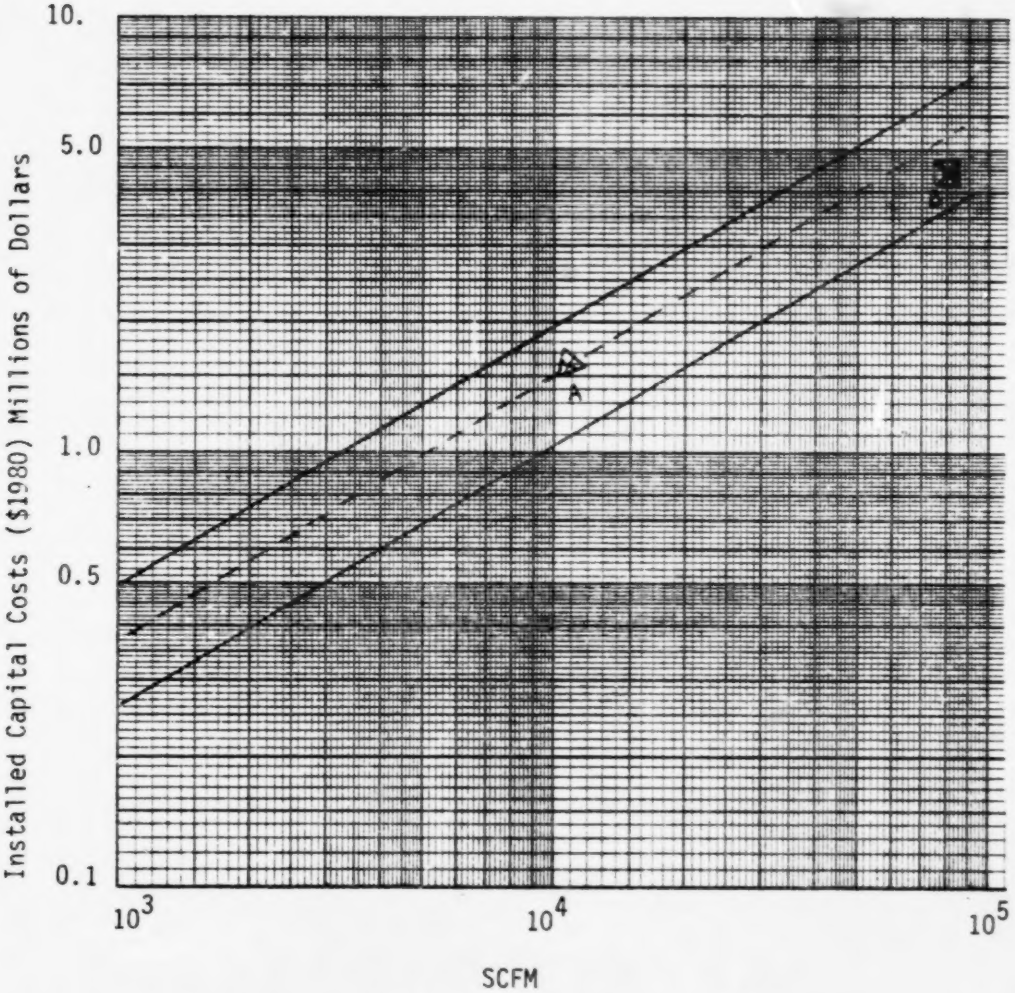

Figure 8-1. Estimated installed capital costs for model plant control systems

Figure 8-1 was developed using the 0.6 power law estimating equation and industry cost data for a medium sized control system[3] represented by point A in Figure 8-1.[14] The equation is as follows:

$$\text{Cost of new system (\$1980)} = \text{Cost of system A (\$1980)}\left(\frac{\text{Capacity of new system, SCFM}}{\text{Capacity of system A, SCFM}}\right)^{0.6}$$

The validity of this equation is demonstrated by the fit, to the cost curve, of the installed capital cost ($1980) of another control system in the industry[2] much larger in capacity than system A, represented by point B in Figure 8-1. Comparisons of the installed capital costs based on the above equation with vendor data and EPA manuals indicate these costs may be on the high side. This would cause the annualized costs for the model plant control systems to be on the high side. For the purpose of this study, this conservatism is acceptable.

Equipment included in the model plant control systems are air filters, humidifiers, fans, motors; 316 stainless steel adsorption vessels, condensers, product coolers, seal pots and piping; carbon steel mixing tanks, distillation columns with bubble cap trays, reflux drums, and dehydrators; appropriate instrumentation and housing structures for this equipment, and the necessary vapor capture systems to achieve the required levels of VOC capture. Annualized costs for the model plant control systems were developed using the assumptions listed in Table 8-2 and the utility usages listed in Table 6-7. Credits for recovered solvent were given based on recoveries of 90 percent of the potentially recoverable solvent. This allows for a 10 percent loss in the distillation and dehydration systems and provides for any solvent in the printed web leaving the finishing line. The installed capital and annualized costs for the model plant control systems may be found in Table 8-4.

8.1.1.2 Cost Analysis and Cost Effectiveness. Table 8-5 contains the total annualized costs for the controlled model plants. Analysis of these costs lead to several conclusions:

TABLE 8-4. ANNUALIZED COSTS FOR VOC CONTROL SYSTEMS

MODEL PLANT	A			B			C			D			E		
Overall VOC Control Efficiency	65	75	85	65	75	85	65	75	85	65	75	85	65	75	85
Carbon Adsorption System Capacity dscm/sec (SCFM)	0.93 (2200)	1.1 (2600)	1.3 (3000)	4.8 (11000)	5.7 (13000)	6.6 (15000)	2.4 (5400)	2.8 (6300)	3.2 (7200)	6.1 (14000)	7.0 (16000)	7.9 (18000)	28 (65000)	33 (76000)	36 (83000)
Installed Capital Cost	607,000	672,000	732,000	1,600,000	1,760,000	1,920,000	1,040,000	1,140,000	1,240,000	1,840,000	2,000,000	2,150,000	4,630,000	5,090,000	5,370,000
Direct Operating Costs															
Operating Labor															
Operator	30,000	30,000	30,000	45,000	45,000	45,000	30,000	30,000	30,000	45,000	45,000	45,000	75,000	75,000	75,000
Supervision	4,500	4,500	4,500	6,800	6,800	6,800	4,500	4,500	4,500	6,800	6,800	6,800	11,000	11,000	11,000
Maintenance	30,000	34,000	37,000	80,000	88,000	96,000	52,000	57,000	62,000	92,000	100,000	110,000	230,000	250,000	270,000
Carbon Replacement	1,100	1,200	1,400	5,200	6,000	6,800	2,600	3,000	3,400	6,500	7,500	8,400	31,000	36,000	41,000
Utilities															
Steam	16,000	19,000	21,000	78,000	90,000	100,000	39,000	45,000	51,000	99,000	110,000	130,000	480,000	540,000	600,000
Electricity	4,200	4,800	5,700	21,000	25,000	29,000	10,000	12,000	14,000	26,000	30,000	33,000	120,000	140,000	160,000
Water	400	400	500	1,800	2,100	2,400	900	1,000	1,200	2,300	2,700	3,000	11,000	13,000	14,000
Indirect Operating Costs															
Overhead	40,000	41,000	42,000	73,000	77,000	80,000	48,000	50,000	52,000	78,000	81,000	85,000	160,000	170,000	180,000
Taxes and Insurance	12,000	13,000	15,000	32,000	35,000	38,000	21,000	23,000	25,000	37,000	40,000	43,000	93,000	100,000	110,000
Administration	12,000	13,000	15,000	32,000	35,000	38,000	21,000	23,000	25,000	37,000	40,000	43,000	93,000	100,000	110,000
Capital Recovery Cost	71,000	79,000	86,000	190,000	210,000	230,000	120,000	130,000	140,000	220,000	230,000	250,000	540,000	600,000	630,000
Credits(-)															
Recovered Solvent	(110,000)	(130,000)	(150,000)	(550,000)	(640,000)	(720,000)	(280,000)	(320,000)	(360,000)	(690,000)	(800,000)	(910,000)	(3,300,000)	(3,800,000)	(4,300,000)
Total Annualized Cost	111,200	109,900	108,100	14,800	(20,100)	(48,000)	69,000	58,500	48,100	(40,400)	(107,000)	(152,800)	(1,456,000)	(1,765,000)	(2,099,000)
$/Mg of solvent recovered	690	590	510	19	(22)	(47)	180	130	93	(41)	(94)	(120)	(310)	(320)	(340)

TABLE 8-5. ANNUALIZED COSTS FOR CONTROLLED MODEL PLANTS

Model Plant	A			B			C			D			E		
Production m²/yr (y²/yr)	1.8×10^7 (21.6×10^6)			1.8×10^7 (21.6×10^6)			0.9×10^7 (10.8×10^6)			11×10^6 (130×10^6)			11×10^6 (130×10^6)		
Total Annualized Cost for Uncontrolled Plant	10,698,000			11,728,000			6,069,000			64,132,000			69,914,000		
Overall VOC Control	65	75	85	65	75	85	65	75	85	65	75	85	65	75	85
Total Annualized Cost for Control System (credits)	111,200	109,900	108,100	14,800	(20,100)	(48,000)	69,000	58,500	48,100	(40,400)	(107,000)	(152,000)	(1,456,000)	(1,765,000)	(2,099,000)
Total Annualized Cost for Controlled Plant	10,809,200	10,807,900	10,848,000	11,742,800	11,707,900	11,680,000	6,138,000	6,127,500	6,117,100	64,091,600	64,025,000	63,979,200	68,458,000	68,149,000	67,815,000
$/sq.m	0.60	0.60	0.60	0.65	0.65	0.65	0.68	0.68	0.68	0.58	0.58	0.58	0.62	0.62	0.62
($/sq.yd)	(0.50)	(0.50)	(0.50)	(0.54)	(0.54)	(0.54)	(0.57)	(0.57)	(0.57)	(0.49)	(0.49)	(0.49)	(0.52)	(0.52)	(0.52)

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1) The total annualized costs for the control systems represent 0.6 to 1.2 percent of the total annualized costs for the controlled model plants.

2) As can be seen in Table 8-5, the incremental costs above the baseline cases (65 percent overall control) for Regulatory Alternatives II and III are negligible.

3) The total annualized costs for both the uncontrolled model plants and the controlled model plants are dominated by raw material costs as can be seen in Tables 8-3 and 8-5.

8.1.1.3 Compliance Monitoring and Performance Testing Costs. Monitoring of the exit gases from the carbon adsorption, solvent recovery systems should not present a major added cost. Monitoring requirements will include the continuous measurement and recording of VOC emissions from the control device if carbon adsorption is used, continuous measurement and recording of flame box temperature if incineration is used. Costs associated with these requirements for carbon adsorption are included in the capital and annualized costs presented in this chapter. In addition, compliance monitoring will require the determination of the weight of VOC (solvent) per unit weight of solids (resins) applied to the web for each waterborne ink used on the print line. Compliance testing also should not be a major added cost. However, a nominal cost of $5,000 and $10,000 per year is included in the operating costs. Appendix D gives more information on emission measurement and continuous monitoring of controlled finishing line facilities.

Performance testing will require the capture and measurement of all fugitive emissions escaping the finishing line. This may require temporary modifications to the structure housing the print line so as to provide a total enclosure of the print line. Performance testing would be infrequent, possibly a one time test. Costs associated with this testing are included in the installed capital costs tabulated in this document.

8.1.1.4 Costs Associated With Increased Water Pollution or Solid Waste Disposal. There are two potential water wastes from the carbon adsorption, solvent recovery system: bottoms product from the distillation column and cooling tower blowdown. Because of complex distillation involved in the solvent recovery system, the bottoms product will contain a very low concentration of solvent (400 ppm) and may be disposed of in a municipal sewer system. The cooling tower blowdown is expected to be small (12 gpm), allowing its disposal in a municipal sewer system. These discharges are not expected to generate any surcharges. The actual amount of any surcharges would be determined by local regulations. In any event, it is unlikely that such charges would be significant costs.

Carbon adsorption has a solid waste also: spent carbon. The spent carbon is usually sold back to processors, reactivated, and then sold again to the original purchaser or other carbon adsorber operators. Therefore, there is no solid waste disposal cost.

8.1.2 Modified or Reconstructed Facilities

The definitions of modified or reconstructed facilities are given in Chapter 5. Modifications and reconstructions may occur in existing facilities, however, modifications and reconstructions are not considered major items of significance in this industry. The cost analysis presented in section 8.1.1 can be applied to a modified or reconstructed facility with the following qualifications:

1) Land requirements for control equipment may be critical for an existing facility.

2) Fugitive capture equipment costs will be higher on older presses due to the generally poor fume containment within older printing lines.

3) Ducting costs may become more expensive if control equipment must be located far from the printing lines.

8.2 OTHER COST CONSIDERATIONS

The flexible vinyl coating and printing industry is governed by regulations concerning the environment within the plant as well as the outside environment.

The costs incurred by other governmental regulations are not expected to limit the financial ability of these plants to comply with the proposed NSPS. Such governmental regulations would consist of the following:

- Standard OSHA work place regulations,
- RCRA regulations affecting disposal of scrap materials,
- Monitoring regulations for vinyl chloride monomer,
- State regulation monitoring requirements for existing facilities.

8.3 REFERENCES

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9.0 ECONOMIC ANALYSIS

9.1 INDUSTRY PROFILE

9.1.1 General Industry Characteristics

9.1.1.1 Introduction. The flexible vinyl coating and printing industry (FVCP) produces a wide variety of diversified products. These products may be divided into two main groups: supported and unsupported vinyl materials. Supported vinyl materials (usually supported with a fabric or paper substrate) may be further subdivided into three major categories: 1) wall coverings; 2) automobile-related products (such as landau roofs, roof headlinings, upholstery, door panels, etc.); and 3) miscellaneous products (such as luggage, handbags, footwear, upholstery, artificial leather, and marine products). Unsupported vinyl materials are used to manufacture shower curtains, book binding, window awnings, shades, and are also printed with a wood grain finish for lamination to furniture.

There are approximately 107 firms producing flexible vinyl coated and printed materials (FVCP) in 112 plants.[1] These firms are identified in Appendix E. The industry is partially contained in SIC 2295 (coated fabrics not rubberized) and SIC 2649 (converted paper and wall coverings). Table 9-1 displays the value of shipments and total quantity produced in the FVCP industry in the latest year available. As the Table reveals, the 1977 value of industry shipments was $981.5 million.[2]

Geographically, most of the industry is concentrated in the northeast and north central regions in the U.S. The bulk of the production comes from Massachusetts, New Jersey, New York, Ohio, Connecticut, and Pennsylvania.[1,2] Figure 9-1 depicts the geographical locations of FVCP operations in the U.S.

Approximately 60 percent of the total output of the industry is produced by twenty firms.[4] Table 9-2 shows these major producers, their location, and the primary end-use markets for their products.

Table 9-1. VALUE OF SHIPMENTS AND TOTAL QUANTITY PRODUCED IN THE FVCP INDUSTRY: 1977

Vinyl Coated Fabrics (SIC 22952)	Value of Shipments (Millions)	Total Quantity Produced Millions of Square Meters (Sq. Yds.)
Lightweight Fabrics	$160.0	137 (164)
Mediumweight Fabrics	214.1	204 (244)
Heavyweight Fabrics	382.2	224 (268)
Not Specified by Kind	50.6	31[a] (37)
	$806.9	596 (713)

Wall Coverings (SIC 26493)	Value of Shipments (Millions)	Total Quantity Produced Millions of kg (lbs.)
Wallpaper	$174.6	63.3[b] (139.3)
Total	$981.5	

[a] Estimate based on 1972 data.

[b] Estimated by dividing value of shipments by the average price per kilogram of wallpaper. The average price per kilogram of wallpaper was taken to be equivalent to the implicit price of wallpaper exports, i.e., the 1977 dollar value of wallpaper exports divided by the total quantity (in millions of kilograms) of wallpaper exported.[3]

Source: Reference 2.

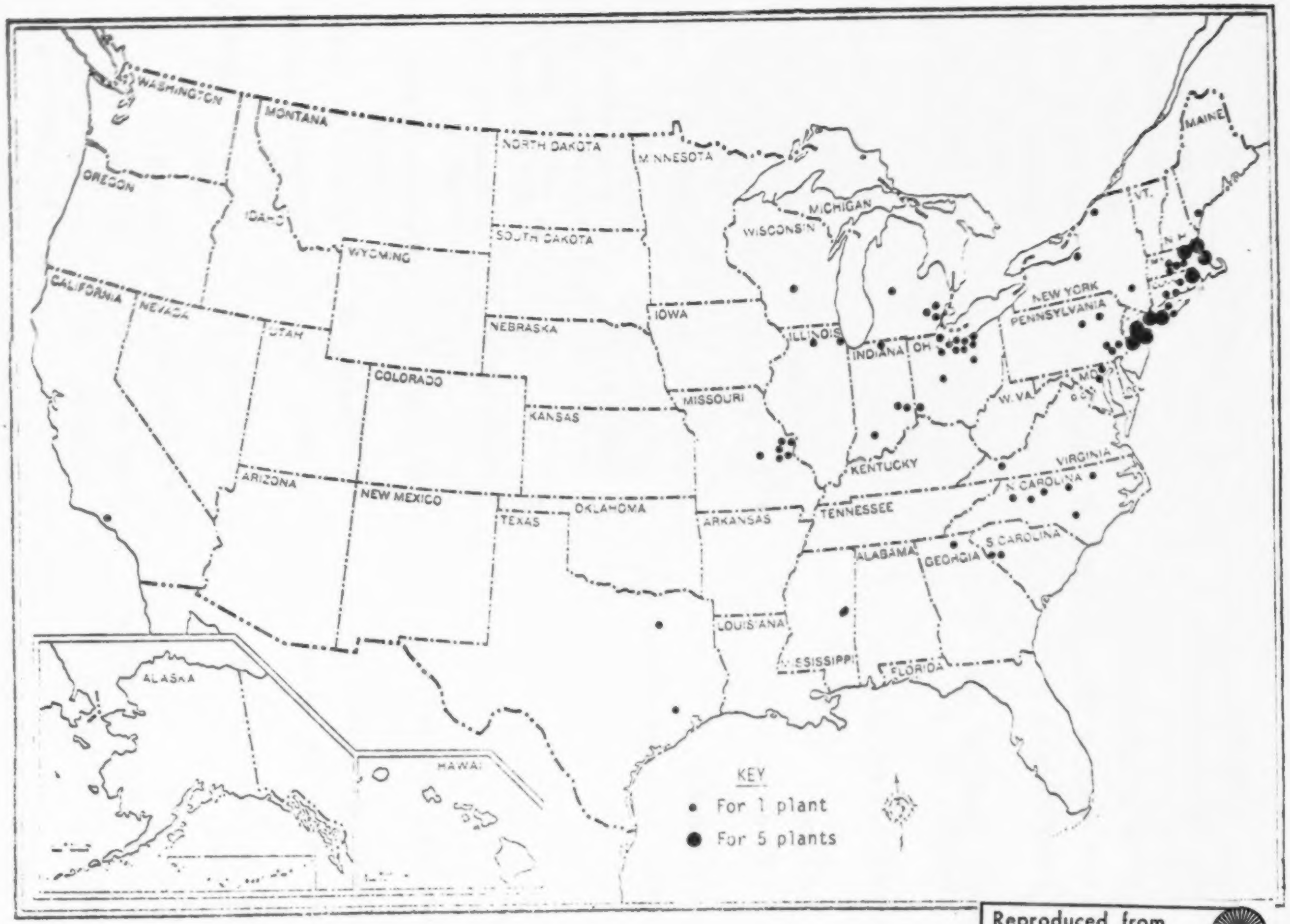
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
MICHIGAN
MAINE
VT.
N.H.
OREGON
IDAHO
SOUTH DAKOTA
WISCONSIN
WYOMING
NEW YORK
PENNSYLVANIA
CALIFORNIA
NEVADA
UTAH
NEBRASKA
IOWA
ILLINOIS
INDIANA
OH
COLORADO
MISSOURI
MD
W. VA
KANSAS
KENTUCKY
VIRGINIA
ARIZONA
NEW MEXICO
N CAROLINA
TEXAS
OKLAHOMA
ARKANSAS
TENNESSEE
S CAROLINA
ALABAMA
GEORGIA
LOUISIANA
MISSISSIPPI
FLORIDA
ALASKA
HAWAII
KEY
● For 1 plant
● For 5 plants

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Figure 9-1. GEOGRAPHICAL LOCATIONS OF VINYL COATING AND PRINTING OPERATIONS IN THE UNITED STATES

Table 9-2. COMPANIES WHICH CONSTITUTE THE MAJORITY OF PRODUCTION IN THE FLEXIBLE VINYL COATING AND PRINTING INDUSTRY

Company	Plant Location	Primary End-Use Markets for Products
Althol Manufacturing Corp. (Emhart)	Butner, NC	Automobile Interiors, Upholstery
B. F. Goodrich Co.	Mariott, OH	Wallcovering
L. E. Carpenter and Co. (Dayco)	Wharton, NJ	Wallcovering
Chrysler Plastic Products Corp.	Sandusky, OH	Automobile Interiors, Landau tops
Borden Chemical Div. (Borden, Inc.)	Columbus, OH Haverhill, Mass. Glen Cove, NY	Wallcovering, Automobile Interiors, Upholstery
Commercial Vinyls, Inc.	New Castle, IN	Footwear, Handbags, Upholstery
Firestone	Pottstown, PA	Luggage, Footwear
Ford Motor Co.	Dearborn, MI	Automobile Interiors, Upholstery
General Motors	Dearborn, MI	Upholstery, Auto Interiors
General Tire and Rubber Co.	Columbus, MS Reading, MA Toledo, OH	Automobile Interiors, Wallcoverings, Luggage, Footwear, Shower Curtains, Upholstery, Marine Uses
Hart and Co.	Brooklyn, NY	Housewares, Mats, Vinyl Fabric
Joanna Western Mills Co.	Chicago, IL	Window Shades, Handbags, Luggage
Masland Duraleather Co.	Mishawaka, IN	Artificial Leather Goods
Pandel Bradford (Compo)	Lowell, MA	Footwear, Luggage, Handbags
Ross and Robert's Inc. (Pervel)	Stratford, CT	Footwear, Handbags, Upholstery
Shelter-rite	Millersburg, OH	Awnings
Standard Coated Products	Hazleton, PA	Wallcovering
Stauffer Chemical Co.	Anderson, SC	Automobile Interiors, Wallcovering
Uniroyal Inc.	Stoughton, WI Port Clinton, OH Mishawaka, IN	Automobile Interiors, Upholstery, Marine Uses
Weymouth Art Leather Co.	Braintree, MA	Leather Goods, Automobile Interiors, Upholstery

Source: References 1 and 4.

9.1.1.2 Production Processes. The production hierarchy for the vinyl coating and printing industry is shown in Figure 9-2. The four basic processing steps in the manufacture of a vinyl-based consumer product are:

- Manufacture of the vinyl coating and ink raw materials (PVC, plasticizers, pigments),
- Formulation of the vinyl and ink coatings,
- Manufacture of the vinyl coated or printed roll, and
- Conversion of the flexible vinyl roll to a consumer good (shoes, luggage, etc.).

The chemical industry manufactures the raw materials used in compounding the vinyls to be coated and printed. PVC resins (a product of vinyl chloride monomer), plasticizers, pigments, and organic solvents are examples of such raw materials. Companies in the FVCP industry may purchase coatings and inks from independent formulators, but the majority formulate their own coatings and inks in house. These latter companies buy raw materials directly from the chemical firm and compound them into the desired coating at the vinyl coating plant. These coatings are transformed into supported or unsupported vinyl sheet by one of the following processes: casting, calendering, or extrusion. Once a vinyl sheet has been produced, it may be printed or topcoated (by rotogravure print heads) to impart a particular color, design, or texture. In some cases the printed vinyl sheet product can be sold to consumers as is. Wallcoverings and shower curtains are examples of such products. The remaining vinyl sheet products are used as raw materials by captive or private manufacturers of shoes, luggage, handbags, automobiles, and upholstery. The final consumer goods are produced by these secondary converters.

The primary component of the topcoats and printing inks applied in the vinyl industry is organic solvent. Oven drying of the printed web releases the solvent as volatile organic compound (VOC) emissions. Both single and multi-component solvent systems are used. The use of solvent-based formulations is expected to continue for several years despite industry efforts to changeover to waterborne formulations. A massive switch to a waterborne formulation system would eliminate VOC emissions; however, three major

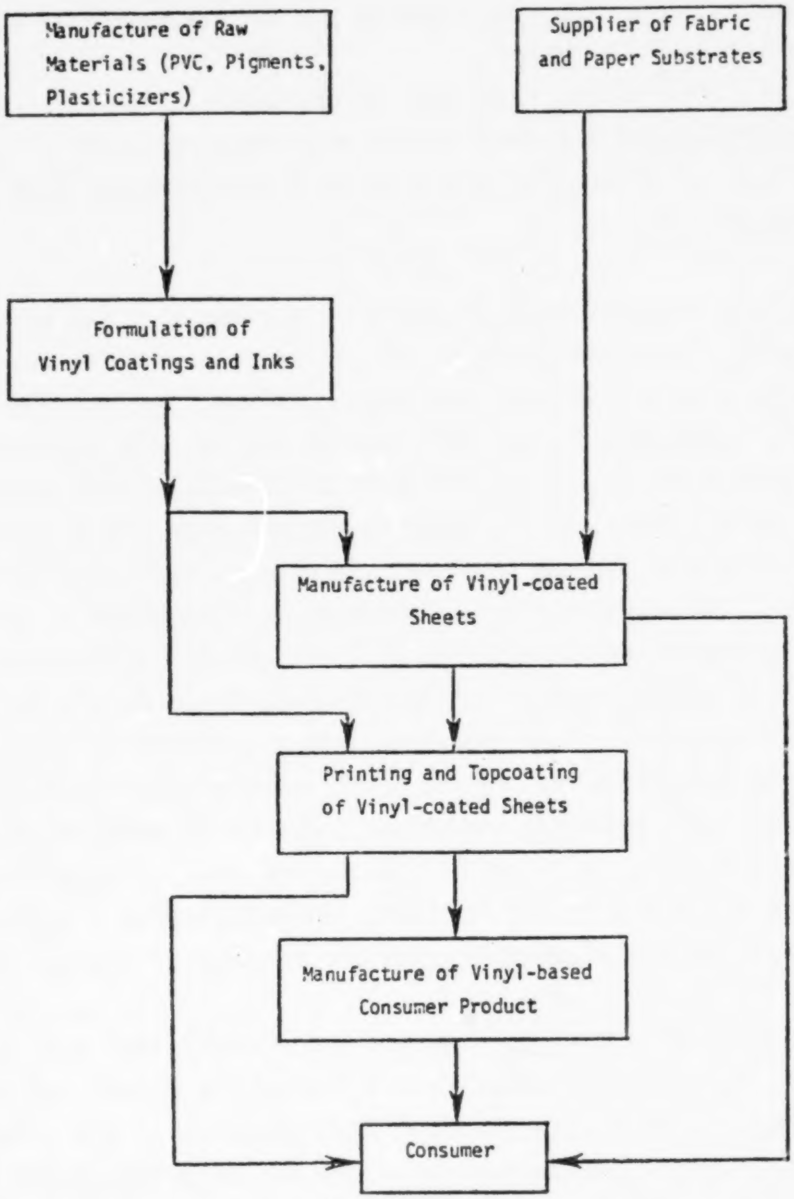
Manufacture of Raw Materials (PVC, Pigments, Plasticizers)
Supplier of Fabric and Paper Substrates
Formulation of Vinyl Coatings and Inks
Manufacture of Vinyl-coated Sheets
Printing and Topcoating of Vinyl-coated Sheets
Manufacture of Vinyl-based Consumer Product
Consumer

Figure 9-2. PRODUCTION HIERARCHY FOR THE FLEXIBLE VINYL COATING AND PRINTING INDUSTRY

problems prohibit such a changeover. These problems are: 1) the technical inability to develop waterborne products that duplicate the specifications of solvent-based products, 2) customer acceptance of waterborne coated products, and 3) waterborne raw materials have higher costs than comparable solvent-based materials.

9.1.2 Firm Characteristics

9.1.2.1 Ownership. Of the twenty major producers listed in Table 9-2, fourteen are publicly-held or owned by publicly-held corporations, and six (Weymouth Art Leather, Hart and Co., Joanna Western Mills, Pervel Industries, Commercial Vinyls, and Masland Duraleather) are privately-held. Only 15 percent of the remaining 87 producers in the FVCP industry are publicly-held.[5] The remaining firms are either privately-held or very small (over-the-counter) companies (so as not to be listed in Standard and Poor's Corporate Records).

9.1.2.2 Vertical/Horizontal Integration. Vertical integration backward to suppliers of polyvinyl chloride (PVC), which is the major raw material used in vinyl coating, is evident in one-fourth of the major producers: Stauffer, B. F. Goodrich (the largest producer of PVC), General Tire, Firestone, Bordon (Columbus Coated Fabrics).[1,6] If one focuses exclusively on wall coverings, two-thirds of the PVC used is produced captively.[7] Only two firms produce their own PVC monomer (the raw material used to make PVC): B. F. Goodrich and Borden.

There also exists a considerable degree of forward integration to final end-use products, particularly for the larger firms. For example, eleven of the major producers manufacture automobile interiors and upholstery, six produce wall coverings, and nine produce a variety of miscellaneous products, such as footwear, handbags, luggage, and artificial leather goods.[1,8]

With respect to horizontal integration, the larger firms are the most diversified, producing a myriad of products. In addition to FVCP products and tires, for example, Goodrich, General Tire, and Uniroyal also manufacture chemicals, plastics, industrial and aerospace products, and rubber goods.[8] The major automobile firms also produce weapons, communications systems, sewage treatment systems, refrigerators and other appliances, and glass.[1] Others, such as Borden and Stauffer Chemicals make food products, industrial chemicals, fertilizers, and cosmetics.[1]

9.1.2.3 Concentration. Table 9-3 shows the trend in concentration in the industry over the 1954-1977 period. The prevailing trend in the first part of this period was toward a decrease in concentration. The end of this trend occurs between 1963 and 1972. The concentration ratios reach their low point in the 1967-1972 period for the vinyl coated fabrics industry (SIC 22952) and in 1963 for the wallcovering industry (SIC 26493).

In recent years the trend has changed toward more concentration in both industrial sectors. This trend is most evident in the category of the four largest manufacturers. For the 22952 SIC code, the concentration ratio has increased from a low of 41 percent in 1967 to 53 percent in 1977. Similarly, for the 26493 SIC code, the concentration ratio has increased from a low of 32 percent in 1963 to 45 percent in 1977.

9.1.3 Industry Trends

9.1.3.1 Historical Production. Because growth within the flexible vinyl coating and printing (FVCP) industry has been uneven, it is best to divide the industry into three subgroups: supported vinyl materials (excluding wall coverings), unsupported vinyl film, and wall coverings. Each of these sub-groups is treated separately below.

9.1.3.1.1 Supported vinyl materials. Table 9-4 displays the value of shipments of supported vinyl materials (coated fabrics) for various end-uses for the 1971-79 period. According to these figures, the annual growth rate was 3.7 percent in dollar volume (see Appendix F for the computation of this growth rate). In order to determine the annual growth rate of physical output, the dollar volumes must be deflated by an appropriate price index. The most appropriate index is the wholesale price of apparel goods (including coated fabrics) which grew at a 4.2 percent annual rate over this period. Thus, the real output growth of this industry segment was negative over the 1970 decade since the price index outpaced the value of shipments (see Appendix G).

Thus, no real output growth is expected over the next five years due to:

a) The switch to smaller cars in general and foreign cars in particular and to the health hazard controversy surrounding vinyl and PVC; and

b) The assumption that past trends will continue into the future.

9.1.3.1.2 Unsupported vinyl film. The value of shipments of unsupported flexible vinyl film is displayed in Table 9-5. As the table reveals, value of shipments grew at an annual rate of 4.51 percent. The price index which

Table 9-3. TRENDS IN CONCENTRATION: 1954-1977

SIC	Year	4 Largest[a]	8 Largest	20 Largest
22952	1954	55%	73%	92%
	1958	47%	67%	90%
	1963	47%	71%	90%
	1967	41%	63%	85%
	1972	43%	62%	83%
	1977	53%	68%	86%
26493	1954	40%	57%	79%
	1958	41%	57%	82%
	1963	32%	48%	75%
	1967	39%	56%	79%
	1972	49%	63%	84%
	1977	45%	63%	87%

[a] Represents the percentage of total output produced by the four largest manufacturers.

Source: Reference 9.

Table 9-4. VALUE OF SHIPMENTS OF SUPPORTED VINYL MATERIALS (EXCLUDING WALL COVERINGS) FOR VARIOUS END-USES
(Millions of Dollars)

End-Use	1971	1973	1975	1977	1979
Automotive	274.40	393.20	330.60	485.90	371.10
Upholstery	113.50	141.00	160.50	161.10	144.00
Luggage	11.90	21.40	22.70	21.60	17.40
Footwear	38.30	40.20	21.40	8.90	10.10
Transportation	18.40	24.30	23.00	27.80	53.80
Garments	3.75	6.98	4.80	5.21	4.65
Handbags	1.86	2.99	1.48	0.59	3.37
Other	26.80	34.50	42.70	49.30	97.70
Total	488.90	664.60	607.20	760.50	702.10

Source: The Chemical Film and Fabric Association.

Table 9-5. VALUE OF SHIPMENTS OF UNSUPPORTED VINYL FILM
(Millions of Dollars)

Year	Value of Shipments
1971	305.3
1973	548.6
1975	513.6
1977	581.7
1979	531.9

Source: The Chemical Film and Fabric Association.

closely approximates this product group (so as to permit the deflation of the series) is that for unsupported plastic (PVC) film. This index advanced at an 8.35 percent annual rate over the 1971-1979 period. Since this index advanced at a faster pace than the value of shipments, a negative growth in real output is implied. Moreover, there is much excess capacity currently in this industrial segment. Accordingly, if it is assumed that past trends will continue, then no growth over the next five years is anticipated in unsupported vinyl film.

9.1.3.1.3 Wall coverings. Table 9-6 shows the volume of shipments for wall coverings over the 1971-79 period. According to the table, the dollar volume of shipments increased at an annual rate of 14.68 percent. The implicit (export) price of wall coverings (found by dividing value of shipments exported by quantity exported) increased at a 5.3 percent annual pace over the same period. Consequently, an 8.9 percent annual growth rate in real output is implied (see Appendix F). This rate will be taken as the projected growth rate over the next five years because it reflects the growing popularity of wall coverings over paint for interior decorating purposes -- a trend reflected in the optimistic forecasts for this market segment by B. F. Goodrich and Peter Sherwood Associates.

9.1.3.2 Demand Determinants. Table 9-7 contains the percentage distribution of the various end-use markets for FVCP over the 1971-1979 period. Upholstery and auto-related commodities account for almost three-quarters of the FVCP produced.[10] The remaining one-quarter is consumed by transportation (other than auto), luggage, footwear, garments, handbags, and other miscellaneous uses (shower curtains, marine canvas, bookbinding, etc.). Wall coverings are excluded from Table 9-7 since they are already a final product.

The outlook for the automobile-related markets does not appear promising over the next few years -- partly due to the switch to smaller cars in general and to the growing market share of foreign cars in particular. Little growth is also expected in end markets such as upholstery, luggage, handbags, apparel, and sporting goods over the next five years.[11] Steady growth, however, is expected for wall coverings, which account for about 7 percent of FVCP industry sales.

9.1.3.3 Raw Materials. The major raw material in the FVCP industry is PVC resin. The largest producer, B. F. Goodrich, has announced plans to double its present capacity (currently 522 millions of kilograms[6]) by 1986. Other producers, such as Borden, Diamond Shamrock, Skintech, Air Products, Tenneco,

Table 9-6. VALUE OF SHIPMENTS OF WALL COVERINGS
(Millions of Dollars)

Year	Value of Shipments
1971	60.6
1973	102.4
1975	119.9
1977	163.9
1979	210.0

Source: The Chemical Film and Fabric Association.

Table 9-7. PERCENTAGE DISTRIBUTION OF END-USE MARKETS FOR FVCP

End-Use	1971	1973	1975	1977	1979
Automotive	56.1%	59.2%	54.4%	63.9%	52.9%
Upholstery	23.2	21.2	26.4	21.2	20.5
Luggage	2.4	3.2	3.7	2.8	2.5
Footwear	7.8	6.0	3.5	1.2	1.4
Transportation	3.7	3.7	3.8	3.7	7.7
Garments	0.7	1.0	0.8	0.7	0.7
Handbags	0.3	0.4	0.2	0.1	0.5
Other	5.8	5.2	7.0	6.5	13.9
Total	100.0	100.0	100.0	100.0	100.0

Source: The Chemical Film and Fabric Association.

Conoco, Georgia-Pacific, and Keysor, have also announced expansions and/or new plants to be completed in the near future (1982).[12] Consequently, an adequate supply should be available in the 1980's.

Table 9-8 shows the producer price index for polyvinyl chloride (PVC) resin over the 1971-1979 period. While the index advanced at a 4.1 percent annual rate over the 1971-73 period, it advanced at an accelerated rate (9.1%) after 1973. Since PVC is a petroleum based product, the accelerated rate reflects the oil embargo in 1973. Future price changes for PVC resin will no doubt continue to be extremely sensitive to oil price changes.

9.1.3.4 Foreign Competition. The major countries to whom the U.S. exports vinyl coated fabrics and materials are: Canada, Dominican Republic, Venezuela, United Kingdom, Italy, Haiti, Japan, and Australia.[3] U.S. exports of wall coverings go to Canada, West Germany, France, United Kingdom, Venezuela, Sweden, Mexico, Australia, Saudi Arabia, and Japan. As Table 9-9 makes clear, exports of FVCP as a percentage of total industry output have remained fairly constant over the 1973-77 period.[14] Hence, exports are not considered a growth center over the next few years.

According to Table 9-9, imports have actually declined in importance over time, from 4 percent in 1973 to 1 percent in 1977 for vinyl coated fabrics.[14] The major trading partners from whom we receive these materials include West Germany, Austria, Switzerland, Belgium, France, India, Canada, and United Kingdom.[15] In contrast to fabrics, imports of wall coverings have been growing in importance, growing at a 12.7 annual rate over the 1973-77 period. Imports of wall coverings flow in mainly from Japan, Korea, West Germany, France, United Kingdom, Sweden, Canada, and Netherlands.[15] Fierce competition from imported wall coverings is expected over the next five years.

9.1.3.5 Prices. Because the FVCP industry consists of a wide variety of diverse products, obtaining a single representative price is quite a challenge. Because of the large amount of resources needed to compute a weighted average price for hundreds of products, an implicit price method is proposed. An implicit price is found by dividing value of shipments (i.e., price times quantity) by quantity. Table 9-10 shows the results of such calculations.

As Table 9-10 reveals, the implicit price per square meter of vinyl coated fabrics was \$0.93 in 1967, \$0.90 in 1973, and \$1.02 in 1977. The implicit price per kilogram of wall coverings was \$1.50 in 1967, \$2.23 in 1972, and \$2.76 in 1977. In an attempt to check the reasonableness of using these

Table 9-8. PRODUCER PRICE INDEX
FOR POLYVINYL CHLORIDE (PVC) RESIN: 1971-1979

Year	Price Index
1971	86.6
1972	88.0
1973	97.4
1974	152.7
1975	170.1
1976	182.2
1977	187.1
1978	191.6
1979	223.8

Source: Reference 13.

Table 9-9. EXPORTS AND IMPORTS OF FVCP AS PERCENTAGE OF TOTAL INDUSTRY OUTPUT

	Year	Exports	Imports[a]
Vinyl Coated Fabrics			
	1977	9%	1%
	1976	8%	2%
	1975	8%	2%
	1974	8%	2%
	1973	8%	4%
Wallcoverings			
	1977	8%	18%
	1976	8%	15%
	1975	7%	10%
	1974	7%	11%
	1973	7%	11%

[a] Import figures are for SIC 2295, while exports are for SIC 22952. In addition, imports are a percentage of new supply (i.e., total industry output plus imports).

Source: Reference 14.

Table 9-10. PRICES OF FVCP

Year	Value of Shipments (millions $)	Quantity Millions Sq. Meters (Millions Sq. Yds.)	Implicit Price Per Sq. Meter (Per Sq. Yd.)	Implicit Export Price Per Sq. Meter (Sq. Yd.)
Vinyl Coated Fabrics				
1977	$806.9	596.0 (713.0)	$1.35 (1.13)	$1.06 (0.87)
1972	601.9	669.8 (814.0)	0.90 (0.74)	0.78 (0.64)
1967	380.7	408.9 (496.9)	0.93 (0.79)	0.62 (0.52)

		Quantity Millions kg. (Millions lb.)	Implicit Price Per kg. (Per lb.)	Implicit Export Price Per kg. (Per lb.)
Wallcoverings				
1977	$174.6	63.4 (139.5)	$2.76 (1.25)	$2.76 (1.25)
1972	83.0	37.5 (82.5)	2.23 (1.01)	2.18 (0.99)
1967	46.2	30.8 (67.8)	1.50 (0.68)	1.59 (0.72)

Source: References 2, 3, and 16.

prices as proxies for FVCP, the implicit price per square meter (and per kilogram) for exports was computed from another source.[3] As is evident from Table 9-10, the two methods of construction yield fairly similar results, especially for wall coverings. Consequently, since export information is available annually (whereas value of shipment data is currently available only up to 1977), the 1979 implicit (export) price of \$1.91 per square meter (\$1.60 per sq. yd.) for vinyl coated fabrics and an implicit (export) price of \$3.41 per kilogram (\$1.55 per pound) for wall coverings will be employed in the economic analysis. These prices will be adjusted to a 1980 level via an appropriate producer price index.

9.1.3.6 Substitutes. Competition by substitutes for flexible vinyl coated and printed products varies depending upon the cost and functional suitability of the substitute products. Polyurethanes, as a substitute for vinyl coated fabrics, offer some outstanding physical properties such as resistance to abrasion, cutting and tearing, and resistance to grease, oils, and chemicals.[17] There was great interest in urethanes as vinyl substitutes during the early 1970's; however, urethanes and vinyl fabrics have some differences in characteristics. Poor surface appearance, poor long-term quality, and higher raw material costs have prevented the substitution of polyurethane for vinyl seat covering materials in the automotive industry.[18] Nonetheless, nylon and certain polyester fabrics are making in-roads in the automotive market. It appears that as the average size of the automobile shrinks, the luxury content of the interior (such as valour upholstery) rises, perhaps as a justification for the higher price tags.

Urethanes, of course, do provide some competition for other supported vinyl products, such as luggage, handbags, footwear, and rainwear. Urethanes possess a wealth of functional properties and are highly cost competitive.[19]

With respect to the unsupported vinyl film segment, polyethylene and polypropylene can be substituted for flexibile vinyl in pool linings, laminations, and packaging, while styrene-butadiene latexes may be substituted in the manufacturing of tablecloths.[20]

Finally, vinyl wall coverings face continual competitive pressures from regular (nonvinyl) wall coverings, paint, and a myriad of panel decorations.

Given the number and nature of substitutes for FVCP products, it is reasonable to infer that the price elasticity of demand is probably relatively elastic.

9.1.4 Growth Projections

9.1.4.1 Projected New Sources

9.1.4.1.1 Supported vinyl materials. The number of new (grass roots) sources in the supported vinyl materials segment is projected to be zero. This projection is based upon the negative growth rate observed (historically) in a previous section (see Section 9.1.3.1.1).

9.1.4.1.2 Unsupported vinyl film. The number of new sources in the unsupported vinyl film group is expected to be zero. This expectation is based upon the negative growth rate observed (historically) in a previous section and the fact that there is excess capacity presently (see Section 9.1.3.1.2).

9.1.4.1.3 Wall coverings. The number of new sources in the wall coverings group is forecasted to be six. This forecast was obtained by employing the following assumptions:

1. The 1979 value of shipments for members of the Chemical Film and Fabric Association (CFFA) was $210 million.
2. CFFA members represent approximately 60 percent of the industry.
3. The 1979 value of shipments for wall coverings was $350 million (210 ÷ .60).
4. The 1979 wholesale price for vinyl wall coverings ranged between $10-20 per roll.[21,22] Since each roll is approximately 3.33 square meters (or 4 square yards), the median price per square meter is $4.50.
5. 77.78 millions of square meters were shipped in 1979 ($350 ÷ $4.50 per square meter).
6. Average capacity utilization is 60 percent.
7. This represents a 1979 capacity of 129.6 millions of square meters (77.78 ÷ .60).
8. Assuming an annual growth rate of 8.9 percent, the 1982 and 1987 capacity is projected to be 167.4 and 256.3 millions of square meters, respectively.

Hence, the projected increase in capacity over the next five years will be 88.9 millions of square meters (i.e., 256.3 - 167.4 = 88.9), or approximately six (6) new sources with an annual output of 9 million square meters (and with a capacity of 15 million square meters) each.

9.1.4.2 Replacement/Reconstruction/Modification. No replacements, reconstructions, or modifications are expected over the next five years.

9.1.4.2.1 Reconstruction/Modification. No major additions in the equipment or changes in the process that would be subject to regulation by the proposed NSPS are projected for the next five years. A more detailed discussion of reconstruction and modification is contained in Chapter 5.

9.1.4.2.2 Replacement. The flexible vinyl and printing industry is relatively young. Most of the existing equipment is less than 15 years old. For this reason, it is very difficult to estimate the actual useful life of one of these printing lines, a statistic essential for projecting the incidence of replacement, modification, and reconstruction. There are some indirect indicators that this type of equipment is long lived. For example, a 30-year life is used for accounting purposes. Many similar machines (intaglio printers) in the textile industry are over 80 years old and continue to operate. Obviously, this type of equipment appears near immune to obsolesence and owners tend to maintain and repair parts of existing lines rather than replace entire lines. For these reasons, the useful life of the vinyl printing lines is expected to be significantly greater than 30 years; therefore no replacements are projected for the next five years.[23,24,25,26,49,50]

9.2 ECONOMIC IMPACT ANALYSIS

9.2.1 Introduction

In the following sections, the potential economic impacts of the proposed regulatory alternatives on the flexible vinyl coating and printing industry (FVCP) are examined. Prior to the impact analysis, a financial profile of the industry is presented. The economic impact analysis then follows with an examination of the profitability, price, and capital availability impacts of each regulatory alternative for five model plants.

This analysis presents estimates of economic impact which may be considered rather modest. In the worst case, a 1.68 percent decline in the return on investment would be experienced by the small modified plants. The price pass-through analysis estimates a worst case increase in price of only 0.047 percent. The capital financing capabilities of the FVCP industry are negatively impacted for all model plants with a decline in the debt service coverage ratios of between 5.58 to 26.23 percent. However, for both regulatory alternatives, the absolute value of all the coverage ratios still attains a level of 3 or better, suggesting that no problems should occur in the capital financing capabilities of the model plants.

9.2.1.1 Financial Profile. Table 9-11 describes annual production for the five model plants in terms of square meters (square yards) and dollars of output. Estimated production for the model plants ranges from 9 to 110 million square meters with a respective range in revenue from 7 to 84 millions of dollars. Model Plant C represents a reconstructed or modified small plant. Model plants A and B represent reconstructed or modified medium plants. Model plants D and E represent new large plants. For a more detailed description of the model plants see Chapter 6.

In order to describe as accurately as possible the different size model plants presented in Table 9-11, financial data was necessary. Financial statistics to proxy for model plants A, B and C were obtained from Annual Statement Studies.[27] Financial statistics for model plants D and E were unavailable from this source since too few reporting firms were large. As an alternative, financial data was taken from the annual reports of the fourteen major manufacturers in the FVCP industry. These statistics are presented in Tables 9-12 through 9-15 for the years 1975 to 1979.

The statistics in these tables are also divided into two subgroups. The first three firms are those whose statistics are available only in a consolidated form, while the last eleven are those whose statistics are separated by divisions (usually speciality plastics or man-made fabrics divisions). Consequently, the statistics on the second group of eleven firms will more accurately reflect the true financial conditions in the FVCP industry. It should be noted, however, that these profit summaries in many cases are for very large divisions. For many of the major producers in the FVCP industry, the divisional statistics reflect a very diversified product line with FVCP just a small part. In other cases, FVCP is the major product in the division.

Tables 9-12 thru 9-14 demonstrate that profit margins for the major producers (individually) showed no discernible trend over the five year period. Profit margins increased or decreased in response to factors such as changes in costs, the degree of product diversification, the degree of saturation in different product markets, and in one case, extremely high start up costs for a new plant.[43] However, the profit margin averages for the eleven firms exhibit a very noticeable downward trend for the five year period. This is due for the most part to the increased cost of raw materials in the production

Table 9-11. ESTIMATED ANNUAL PRODUCTION AND REVENUES FOR THE FLEXIBLE VINYL COATING AND PRINTING MODEL PLANTS (1980)

	Model Plants				
	A	B	C	D	E
Annual Production[a] millions of m^2 (millions yd^2)	18 (21.6)	18 (21.6)	9 (10.8)	110 (130)	110 (130)
Annual Revenue[b] ($ millions)	12.883	13.582	7.173	80.755	84.029

[a] Annual production volumes were estimated by Radian Corp.

[b] Annual Revenues were estimated from costs of sales provided by Radian Corp.

Source: Reference No. 28.

Table 9-12. GROSS PROFIT MARGINS FOR THE MAJOR MANUFACTURERS OF PVC COATED FABRICS AND FILMS[a]

Company	Year					Five Year Average
	1975	1976	1977	1978	1979	
Chrysler	.078	.128	.102	.075	.031	
Ford Motor Co.	.121	.151	.156	.148	.156	
General Motors	.163	.194	.191	.189	.158	
Althol Manufacturing (Sub. of Emhart)	.327[b]	.314	.326	.315	.293	
Borden Inc.	.316	.358	.364	.242	.231	
Compo	.195	.228	.197	.255	.260	
L.E. Carpenter (Sub. of Dayco)	.211	.213	.219	.234	.204	
Firestone	.317	.280	.252	.246	.259	
General Tire and Rubber Co.	.196	.194	.223	.234	.210	
Goodrich	.230	.229	.235	.282	.323	
Harte and Co. (Sub. of Diamond Shamrock)	.348	.192	.150	.218	.243	
Pervel (Sub. of Bemis)	.169	.153	.199	.185	.193	
Stauffer Chemical Co.	.234	.245	.231	.197	.017	
Uniroyal Inc.	.275	.239	.214	.219	.221	
All fourteen Firms Average	.227	.223	.218	.217	.198	.217
Last Eleven Firms Average[c]	.256	.240	.237	.239	.220	.238

[a] Gross profits (i.e., profits before depreciation, selling and administrative expenses, other expenses, interest and taxes) divided by sales.

[b] Estimated using industry average growth for the year. Data for Althol Manufacturing was unavailable for this year.

[c] This average disregards the data for Chrysler, Ford, and GM (Annual Reports are consolidated) and includes only financial data disaggregated by divisions.

Source: References 29 through 42.

Table 9-13. OPERATING PROFIT MARGINS FOR THE MAJOR MANUFACTURERS OF PVC COATED FABRICS AND FILMS[a]

	Year					
Company	1975	1976	1977	1978	1979	Five Year Average
Chrysler	.000	.039	.021	-.015	-.074	
Ford Motor Co.	.018	.055	.073	.092	.103	
General Motors	.070	.107	.116	.105	.072	
Althol Manufacturing (Sub. of Emhart)	.078[b]	.093	.109	.108	.089	
Borden Inc.	.136	.129	.135	.119	.114	
Compo	.036	.074	.025	.091	.109	
L.E. Carpenter (Sub. of Dayco)	.020	.030	.054	.050	.017	
Firestone	.141	.105	.085	.095	.096	
General Tire and Rubber Co.	.088	.083	.108	.111	.078	
Goodrich	.037	.072	.051	.062	.104	
Harte and Co. (Sub. of Diamond Shamrock)	.192	.079	.046	.062	.102	
Pervel (Sub. Bemis)	-.008	-.006	.039	.026	.027	
Stauffer Chemical Co.	.080	.113	.082	.029	-.205	
Uniroyal Inc.	.058	.042	.038	.044	.045	
All fourteen Firms Average	.068	.073	.070	.070	.048	.066
Last Eleven Firms Average[c]	.078	.074	.070	.072	.052	.069

[a] Operating Income (i.e., income before other expenses, interest and taxes) divided by sales.

[b] Estimated using the industry average growth rate for the year. Data for Althol Manufacturing was unavailable for this year.

[c] This average disregards the data for Chrysler, Ford, and GM (Annual Reports are consolidated) and includes only financial data disaggregated by divisions.

Source: References 29 through 42.

Table 9-14. NET PROFIT MARGINS FOR THE MAJOR MANUFACTURERS OF PVC COATED FABRICS AND FILMS[a]

Company	Year 1975	 1976	 1977	 1978	 1979	Five Year Average
Chrysler	-.030	.034	.012	-.015	-.091	
Ford Motor Co.	.008	.035	.045	.061	.109	
General Motors	.035	.062	.061	.055	.044	
Althol Manufacturing (Sub. of Emhart)	.024[b]	.039	.046	.049	.036	
Borden Inc.	.058	.059	.065	.063	.061	
Compo	.013	.034	.015	.017	.026	
L.E. Carpenter (Sub. of Dayco)	-.005	.001	.016	.013	-.006	
Firestone	.056	.036	.029	.029	.038	
General Tire and Rubber Co.	.033	.030	.044	.048	.030	
Goodrich	.004	.024	.016	.024	.054	
Harte and Co. (Sub. of Diamond Shamrock)	.160	.025	.005	.010	.027	
Pervel (Sub. Bemis)	-.020	-.028	.016	.001	.001	
Stauffer Chemical Co.	.010	.029	.014	-.025	-.150	
Uniroyal Inc.	.016	.007	.005	.007	.003	
All fourteen Firms Average	.026	.028	.028	.024	.013	.024
Last Eleven Firms Average[c]	.032	.023	.025	.021	.011	.022

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[a] Net profits divided by sales.

[b] Estimated using the industry average growth rate for the year. Data for Althol Manufacturing was unavailable for this year.

[c] This average disregards the data for Chrysler, Ford, and GM (Annual Reports are consolidated) and includes only financial data disaggregated by divisions.

Source: References 29 through 42.

Table 9-15. NET PROFITS TO ASSETS RATIO FOR THE MAJOR MANUFACTURERS OF PVC COATED FABRICS AND FILMS[a]

Company	Year 1975	 1976	 1977	 1978	 1979	Five Year Average
Chrysler	-.041	.060	.021	-.029	-.165	
Ford Motor Co.	.013	.063	.088	.136	.236	
General Motors	.058	.119	.125	.115	.090	
- - - - - - - - - -						
Althol Manufacturing (Sub. of Emhart)	.075[b]	.096	.109	.112	.084	
Borden Inc.	.056	.086	.089	.081	.080	
Compo	.027	.082	.024	.044	.063	
L.E. Carpenter (Sub. of Dayco)	-.006	.006	.032	.024	-.013	
Firestone	.077	.070	.126	.074	.096	
General Tire and Rubber Co.	.057	.058	.096	.095	.059	
Goodrich	.020	.027	.023	.033	.091	
Harte and Co. (Sub. of Diamond Shamrock)	.117	.026	.004	.006	.027	
Pervel (Sub. Bemis)	-.036	-.075	.036	.003	.002	
Stauffer Chemical Co.	.011	.034	.014	-.018	-.115	
Uniroyal Inc.	.032	.012	.008	.014	.006	
All fourteen Firms Average	.033	.047	.057	.049	.035	.044
Last Eleven Firms Average[c]	.039	.038	.051	.043	.039	.042

[a] Net profits divided by total assets.

[b] Estimated using the industry average growth rate for that year. Data for Althol Manufacturing was unavailable for this year.

[c] This average disregards the data for Chrysler, Ford, and GM (Annual Reports are consolidated) and includes only financial data disaggregated by divisions.

Source: References 29 through 42.

process. The profit margin squeeze was also exacerbated by a less than satisfactory ability to pass these higher costs along to the consumer.[44] As a result, profit margins for 1979 were well below the average for the five year period.

Table 9-15 demonstrates a similar trend in the net profits to asset ratios for the major producers in the FVCP industry. Return on assets for the subgroup of eleven major producers rebounded from a low of .038 in 1976 to .051 in 1977, but then proceeded to decline to .039 in 1979. This downward trend can be attributed to the same factors causing the downward trend in the profit margins.

Financial ratios averaged for the five year period for the five model plants are summarized in Table 9-16. When considering the size of the model plants, the smallest, model plant C, exhibits the largest net profit margin and return on assets. Operating profits, on the other hand, are the lowest for model plant C. Other expenses, such as general corporate expenses and interest expenses, are of less importance to the smallest model plant which seems to demonstrate a much tighter control over these types of expenses. This results in a much larger net income margin (as a percent of sales) for model plant C.

9.2.1.2 Pricing and Market Structure. To assess the impact of the regulatory alternatives on the FVCP product prices, it is necessary to examine the pricing behavior and the market structure in the industry. Pricing in the industry depends on the demand characteristics of the FVCP products and on the market structure in the FVCP industry.

The major demand characteristic which influences pricing decisions is the demand elasticity. It is quite difficult to quantitatively assess a specific demand elasticity since the number of products employing FVCP fabrics and films in their production process is so numerous. A qualitative approach can be substituted adequately. The major determinant of the demand elasticity of PVC fabrics, films, and wallpaper is the number of available substitute products and the ease with which these products can be substituted for FVCP materials. Many of the end use markets for the FVCP products have readily available substitutes at their disposal. The supported vinyl fabrics sector has cloth fabric as a very good substitute. Substitutes for the unsupported vinyl film are other plastic films, such as polyethylene and polypropylene. Vinyl wall coverings have paper and paint as readily available substitutes. The ease with which these products can be substituted for vinyl creates a very elastic demand for FVCP products.

Table 9-16. SUMMARY FINANCIAL RATIOS FOR THE 65% VOC CONTROL LEVEL (BASELINE CASE)[a]

	Model Plants				
	A	B	C	D	E
Cost of Sales (% of Sales)	79.90	79.90	77.75	76.20	76.20
Gross Profits (% of Sales)	20.10	20.10	22.25	23.80	23.80
Operating Profits (% of Sales)	4.67	4.67	4.55	6.90	6.90
EBIT (% of Sales)	3.46	3.46	4.25	3.90	3.90
Net Income (% of Sales)	1.97	1.97	2.42	2.22	2.22
EBIT/Assets	7.7%	7.7%	7.9%	7.3%	7.3%
Baseline ROI[b]	4.16%	4.16%	4.27%	3.94%	3.94%
Depreciation/Revenue	2.18%	2.18%	2.13%	2.94%	2.94%
CMLTD/Assets[c]	2.04%	2.04%	1.95%	0.85%	0.85%

[a] The ratios for model plants A, B and C represent five year historical averages from Robert Morris Associates. The ratios for model plants D and E are five year historical averages (by division) from the eleven major manufacturers' annual reports.

[b] (EBIT/Assets) x (1-.46). The average tax rate for the major manufacturers is .46.

[c] Current Maturity Long Term Debt ÷ Assets.

Sources: References 27 and 29 through 42.

Evidence that complete price pass through is very difficult in the FVCP industry is presented in a few of the annual reports of the major producers. One manufacturer attributed the majority of their recent profit margin squeeze to their ability to only pass through less than half of the increase in petrochemical costs.[45] Evidence was presented earlier in Table 9-14 that profit margins have been rather unstable with a declining trend for the last five years. This implies that the firms in the industry have very little market power over price and demand is relatively elastic.

A description of the FVCP industry market structure is most difficult because of the varied end uses of FVCP products and the degree of vertical integration as described in Section 9.1.2.2. Market structure per se in the FVCP industry is generally not considered a significant determinant for pricing behavior due to the extreme importance of the availability of substitutes in the market. However, it is important to examine the market structures of both the captive and merchant markets of the supported, unsupported, and wall covering sectors in the industry.

The industry can be described as a generally competitive market but with a few isolated segments which exercise limited market power over prices. Both the merchant market in the supported and unsupported sectors as well as the captive unsupported sector exhibit characteristics of a competitive market structure. These sectors of the industry are characterized as having a large number of firms producing very similar products with little or no market power over prices.

In the captive portion of the supported vinyl sector the auto industry is an important producer. A majority (52.9%) of the supported vinyl produced in 1979 was used by the auto industry.[46] Much of this supported vinyl was captively produced with its cost representing only a small portion of the final product price. The large auto firms have a large degree of power over pricing in the final product market; however, the captively produced vinyl must still remain cost competitive with substitutes such as cloth fabrics and leather.

The market structure for the wall covering sector can also be described as competitive. Close examination of the wall covering sector at the seven-digit SIC level reveals that the vinyl paper wall covering sector (SIC 2649325) is composed of only fourteen companies (sales of $100,000 or more) with total value of shipments of $36.2 million (1977 dollars).[47] The vinyl fabric wall covering sector (SIC 2649331) is composed of nine companies (sales of $100,000 or more) with total value of shipments of $36.9 million (1977 dollars). Although these figures might be suggestive of a significant degree of market power, demand considerations prevent any such market power over pricing. Substitutes, such as regular paper wall coverings, panel decorations, and paint, provide enough competition to prevent any oligopolistic behavior from occurring. Therefore, this sector can also be considered competitive in its market structure.

9.2.2 Potential Economic Impacts

9.2.2.1 Economic Impact Assessment Methodology. Three types of economic impact analyses are examined:

1. Return-on-investment (ROI),
2. Price pass-through and
3. Capital availability.

The return on investment analysis examines the impact of control costs on model plant viability and the attractiveness of investment in new plants. The basic measure of ROI employed in the following analysis can be obtained as follows:

$$\text{Return on Investment} = \frac{\text{Net Profit}}{\text{Total Investment}} \qquad (1)$$

The measure of investment in this analysis is total assets (which are equal to debt plus equity). The ROI analysis will also assume that the total cost of control will be fully absorbed by the impacted firms without any price pass-through. The impact on ROI will be a worst case situation.

Caution must be exercised in the application of this ROI analysis to new plants since the data is based on existing firms and plants. The ROI presented here will most likely be overstated for two reasons. First, total assets used in the calculations will be net of depreciation, whereas a new plant's asset level would be void of any deductions for depreciation. Second, assets purchased in the past are not valued at replacement cost. Assets of existing plants would be understated by the impact inflation has on replacement costs. However, some of the effect that these two factors have in reducing ROI for new plants would be offset by expected cost savings from more efficient new plant operations.

Price pass-through analysis examines the maximum price increase which would take place if firms passed control costs through to customers in the form of higher prices. It is assumed in the analysis that firms will increase operating income by raising prices in order to maintain precontrol ROI after the imposition of controls. These increases would be a worst case situation.

The results of the ROI and price pass-through analysis must be interpreted very carefully because they were based on worst case assumptions. By relaxing these worst case assumptions, the results would be more realistic and more consistent with the qualitative scenario presented in Section 9.2.1.2.

Whether or not firms can meet increased annual debt service costs under controls is assessed in the debt service coverage analysis. The debt service coverage ratio is calculated by dividing a firm's cash flow (net income after taxes plus depreciation) by its level of current maturity of long-term debt (CMLTD). The resulting ratio provides an index describing the cash (capital) available to a firm for retiring long-term debt commitments. The ratio is frequently used by the banking community for making loan decisions. If the ratio for a firm is two or greater, debt service coverage is considered to be healthy. A ratio less than one indicates that annual debt service costs cannot be met and that firms will therefore find their access to capital restricted.[48]

9.2.2.2 Return on Investment Analysis. Using the necessary ratios presented in Table 9-16, pro forma income statements for each model plant are calculated and presented in Table 9-17 for the baseline case. It is assumed that these costs account for costs associated with a 65% level of pollution control. After the net income before taxes (EBIT) is calculated, the level of assets can be estimated from the available EBIT/Assets ratio. Baseline ROI can then be calculated by dividing net income by the estimated assets. Tables 9-18 and 9-19 employ similar calculations to obtain the ROI's for the 75% and 85% levels of pollution control. Appropriate adjustments are made to cost of sales and assets to account for the additional costs of control.

The results presented in Tables 9-18 suggests a change in ROI for the 75 percent level of control to range between a 0.96 percent decline and an 8.38 percent increase. Table 9-19 suggests a range of between a 1.68 percent decline and a 17.77 percent increase in ROI for the 85 percent of control. The favorable impact on four of the five model plants is due to the large solvent recovery credits that more than offset the annualized cost of control. For model plant A the solvent recovery credit is also sufficient to offset the annualized cost of control and result in an increase in net income. However, the percent increase in the level of assets is much larger than the percent increase in net income resulting in a decrease in the net income/assets ratio. Conversely, ROIs for model plants B through E increase because the percent increase in the level of assets is much smaller than the percent increase in net income.

Table 9-17. ROI ANALYSIS OF THE 65 PERCENT VOC CONTROL LEVEL (BASELINE)

($ million)

	Model Plants				
	A	B	C	D	E
Sales[a]	12.883	13.583	7.173	80.755	84.029
Cost of Sales[b]	10.293	10.852	5.577	61.535	64.030
Gross Profits	2.590	2.730	1.596	19.220	19.999
Operating Expenses	1.988	2.096	1.273	13,648	14.201
Operating Profits[c]	.602	.634	.323	5.572	5.798
Other Expenses	.157	.166	.021	2.423	2.521
EBIT[d]	.445	.468	.302	3.149	3.277
Income Tax (.46 x EBIT)	.204	.215	.139	1.449	1.507
Net Income[e]	.241	.253	.163	1.700	1.770
EBIT/Assets	7.7%	7.7%	7.9%	7.3%	7.3%
Assets[f]	5.779	6.078	3.823	43.137	44.890
ROI[g]	4.17%	4.16%	4.26%	3.94%	3.94%

[a] Cost of Sales ÷ (1-Gross Profit margin).

[b] Cost estimates were obtained from Radian Corp.

[c] Sales x Operating profit margin.

[d] Sales x (EBIT/Sales).

[e] Sales x Net Income Margin.

[f] EBIT ÷ (EBIT/Assets).

[g] Net Income ÷ Assets.

Table 9-18. ROI ANALYSIS OF THE 75 PERCENT VOC CONTROL LEVEL ($ million)

	Model Plants				
	A	B	C	D	E
Sales[a]	12.883	13.582	7.173	80.755	84.029
Cost of Sales[b]	10.292	10.817	5.567	61.469	63.721
Gross Profits	2.591	2.765	1.606	19.286	20.308
Operating Expenses	1.988	2.096	1.273	13.648	14.201
Operating Profits	.603	.669	.333	5.638	6.107
Other Expenses	.157	.166	.021	2.422	2.521
EBIT	.446	.503	.312	3.216	3.586
Income Tax	.205	.231	.144	1.479	1.650
Net Income	.241	.272	.168	1.737	1.936
Assets (65% level)	5.771	6.086	3.814	43.143	44.892
Additional Capital[c]	.065	.160	.100	.160	.460
Assets (75% level)	5.836	6.246	3.914	43.303	45.352
ROI (75% level)[d]	4.13%	4.36%	4.29%	4.03%	4.27%
% Change from Baseline	-0.96%	+4.81%	+0.70%	+2.28%	+8.38%

[a] From Table 9-17.

[b] Baseline cost of sales + the annualized cost of pollution control for the 75% level.

[c] Capital Cost (75% level) - Capital Costs (65% level).

[d] Net Income ÷ Assets (75% level).

Table 9-19. ROI ANALYSIS OF THE 85 PERCENT VOC CONTROL LEVEL ($ million)

	Model Plants				
	A	B	C	D	E
Sales[a]	12.883	13.582	7.173	80.755	84.029
Cost of Sales[b]	10.289	10.789	5.556	61.423	63.387
Gross Profits	2.594	2.793	1.617	19.332	20.642
Operating Expenses	1.988	2.096	1.273	13.648	14.201
Operating Profits	.606	.697	.344	5.684	6.441
Other Expenses	.157	.166	.022	2.422	2.521
EBIT	.449	.531	.322	3.261	3.920
Income Tax	.207	.244	.148	1.500	1.803
Net Income	.242	.287	.174	1.762	2.117
Assets (65% level)	5.771	6.086	3.814	43.143	44.892
Additional Capital[c]	.125	.320	.200	.310	.740
Assets (85% level)	5.896	6.406	4.014	43.453	45.632
ROI (85% level)[d]	4.10%	4.48%	4.33%	4.05%	4.64%
% Change from Baseline	-1.68%	+7.69%	+1.64%	+2.79%	+17.77%

[a] From Table 9-17.

[b] Baseline cost of sales + the annualized cost of pollution control for the 85% level.

[c] Capital Cost (85% level) - Capital Costs (65% level).

[d] Net Income ÷ Assets (85% level).

9.2.2.3 Price Pass-Through Analysis. The price pass-through analysis will employ equation (1) utilized earlier, but in a modified form. The form of ROI to be used here is:

$$ROI^* = \frac{(REV^* - TC)(1 - t)}{I} \quad (2)$$

where: ROI* = The baseline ROI levels to be maintained.

REV* = The revenue level necessary to maintain ROI* after controls are implemented.

TC = Total costs including the additional VOC control costs.

t = The federal tax rate for the industry (.46).

I = The asset level including the additional capital costs of VOC controls.

Volume of shipments is assumed to be constant after the controls are implemented; hence, any percentage change in revenue will be exactly equal to a percentage change in price. After solving for the revenue level in equation (2), equation (3) can be used to solve for the percent change in price necessary to maintain the baseline ROI.

$$\% \text{ Change in Price} = \left[\frac{REV^* - REV}{REV}\right] \times 100 \quad (3)$$

where: REV* = Post NSPS revenue level

REV = Baseline revenue level

Since four of the ROI impacts are positive, the following price pass through analysis will be limited to the one negative case (model plant A).

Using equations (2) and (3) and the information in Tables 9-17, 9-18, and 9-19 for model plant A, the price pass through calculations for both the 75 percent and the 85 percent level of control are as follows:

- o 75 percent VOC control level:

$$ROI = 0.0417 = \frac{(REV^* - 12.437)(1 - .46)}{5.836}$$

$$REV^* = 12.888$$

$$\% \text{ Price Change} = \frac{12.888 - 12.883}{12.883} \times 100 = 0.039\%$$

- o 85 percent VOC Control Level:

$$ROI = 0.0417 = \frac{(REV^* - 12.434)(1 - .46)}{5.896}$$

$$REV^* = 12.889$$

$$\% \text{ Price Change} = \frac{12.889 - 12.883}{12.883} \times 100 = 0.047\%$$

In summary, the worst case would suggest a very modest price increase for Model Plant A of between 0.039 to 0.047 percent. The worst possible case for model plants B thru E would be no price change whatsoever, since the positive impacts on ROI provide no incentive for a price increase.

9.2.2.4 Capital Availability Analysis. Table 9-20 presents the results of the debt service coverage analysis. For the baseline case, all of the model plants exhibit very healthy debt service coverage ratios of at least 4. Model plants D and E are in an especially healthy position with ratios of 11.10.

The additional capital requirements for the 75 percent regulatory alternative reduce the debt service coverage ratios by 5.58 to 16.16 percent depending upon the model plant size. Although this relative change seems rather large, the absolute level of the ratios do not fall below a healthy level of 3 for any of the model plants. For the 85 percent regulatory alternative, the debt service coverage ratio is reduced by 10.34 to 26.23 percent. Again, in no case does the absolute level of the ratio fall below 3.

Especially noticable from Table 9-20 is the disproportionate impacts on the smallest and largest model plants. Model plant C would experience the most negative impact under either regulatory alternative while the larger model plant D is impacted the least under either regulatory alternative. Model plant A, however, was the only model plant which exhibited negative impacts in the ROI and price pass-through analysis, and it is impacted relatively little compared to the other model plants.

This unexpected impact on model plant C is due primarily to the large increase in its CMLTD necessary to pay back the increased debt. Table 9-21 shows the percent increases in CMLTD for each regulatory alternative. An examination of the percent increases in CMLTD reveals a pattern similar to the pattern of decreases in the debt service coverage ratios.

9.2.2.5 Small Business Impact. The Regulatory Flexibility Act requires, among other things, the economic impact assessment to determine whether or not a regulation is likely to have a significant impact on a significant number of small businesses. If the analysis shows a likely significant impact, the Agency must prepare and publish a regulatory flexibility analysis. This section assesses the likelihood of such a significant impact. It concludes that a significant impact is not expected.

The assessment in Sections 9.2.2.1 through 9.2.2.4 examined small businesses through the analysis of three small model plants of a size of 1 print

Table 9-20. DEBT SERVICE COVERAGE ANALYSIS

($ Million)

	Model Plants				
	A	B	C	D	E
Baseline 65%					
Net Income After Tax	0.241	0.253	0.163	1.700	1.770
Depreciation[a]	0.281	0.296	0.153	2.374	2.470
Cash Flow[b]	0.522	0.549	0.316	4.074	4.240
CMLTD[c]	0.118	0.124	0.074	0.367	0.382
Debt Service Coverage Ratio[d]	4.42	4.42	4.27	11.10	11.10
75% Level					
Net Income After Taxes	0.241	0.272	0.168	1.737	1.936
Depreciation[e]	0.284	0.304	0.158	2.382	2.493
Cash Flow[b]	0.525	0.576	0.326	4.119	4.429
CMLTD[f]	0.128	0.150	0.091	0.393	0.457
Debt Service Coverage Ratio[d]	4.10	3.84	3.58	10.48	9.69
Percent Change from Baseline	-7.24	-13.12	-16.16	-5.58	-12.69
85% Level					
Net Income After Taxes	0.242	0.287	0.174	1.762	2.117
Depreciation[e]	0.287	0.312	0.163	2.390	2.507
Cash Flow[b]	0.529	0.599	0.337	4.152	4.624
CMLTD[f]	0.138	0.176	0.107	0.417	0.502
Debt Service Coverage Ratio[d]	3.83	3.40	3.15	9.95	9.21
Percent Change from Baseline	-13.35	-23.08	-26.23	-10.34	-17.03

[a] (Dep./Revenue) x Revenue.

[b] Net income after taxes plus depreciation.

[c] Current maturity long term debt (CMLTD) = (CMLTD/Assets) x Assets.

[d] Cash Flow/CMLTD.

[e] Baseline depreciation + (.05 x capital cost of control) (assumes a 20 year life of equipment).

[f] Baseline CMLTD + [Capital Recovery Factor (1.63) x Incremental Capital Control Cost].

Table 9-21. PERCENT INCREASES IN CMLTD

	Model Plant				
	A	B	C	D	E
75% Alternative	8.5%	21.0%	23.0%	7.1%	19.6%
85% Alternative	16.9%	41.9%	44.6%	13.6%	31.4%

line each. The assessment examined the impact categories of price increases, changes in return on investment, and capital availability. These impact categories were examined for absolute small plant impacts and for differential impacts between small and large plants.

The estimated number of plants to be impacted by a regulation on this industry over the next five years is six, which is only 5 percent of the 112 plants, or 107 firms, in this industry. The analysis did pinpoint the size of these six plants to be small. However, even in such an event the size of the impacts are not considered significant.

According to the results presented earlier in Tables 9-18 and 9-19, differential impacts of a level that are not considered significant can be expected to occur with respect to a change in ROI. For the 75 percent regulatory alternative, changes in ROI will range between a decrease of 0.96 percent to an increase of 4.81 percent for the smaller modified model plants as opposed to an increase of between 2.28 to 8.38 percent for the new larger model plants.

A similar pattern is evident for the 85 percent regulatory alternative. Although the ranges overlap, the extreme endpoints would seem to indicate that the larger model plants will acquire cost advantages which would place the smaller model plants at a disadvantage although the total impact is not considered significant. This possibility could become more pronounced because the incentive exists for the larger model plants to lower prices, thus placing a small impact on plants similar to model plant A.

The debt service coverage results from Table 9-20 provides a similar pattern of differential impacts. For the 75 percent regulatory alternative, changes in the debt service coverage ratio ranges between a decrease of 7.24 to 16.16 percent for the smaller modified model plants as compared to a decrease of between 5.58 to 12.69 percent for the new larger model plants. A similar pattern results for the 85 percent regulatory alternative. Again, the exact pattern is somewhat obscured by the overlap of the ranges; however, the extreme endpoints seem to indicate that the smaller model plants are impacted slightly more than the larger model plants.

The potential price increases are significantly less than the 5 percent level contained in Executive Order 12291 and cost savings occur in some regulatory alternatives. Slight differential impacts occur between the small and large model plants with regard to maximum price increases associated with the

Table 9-22. FIFTH YEAR ANNUALIZED SAVINGS OF COMPLIANCE[a]

	Model Plant With Worst Case	Lowest Annualized Savings Per Plant	Total Fifth Year Annualized Savings of Compliance
6 New Plants, 75% level of Control	C	$10,000	$ 60,000
6 New Plants, 85% level of control	C	$21,000	$126,000

[a] As mentioned in Section 9.2.2.2 the solvent recovery credits more than offset the annualized cost of control. Thus, in both the 75% and 85% levels of control, there is savings rather than costs.

regulatory alternatives. With the 75 percent regulatory alternative, the maximum price increase for the small model plant, A, is .039 percent while a slight savings occurs for the large model plant. With the 85 percent regulatory alternative, the maximum price increases for model plant A is .047 percent while a savings occurs for the large model plant.

9.3 POTENTIAL SOCIOECONOMIC AND INFLATIONARY IMPACTS

The purpose of Section 9.3 is to address those tests of macroeconomic impact to determine whether or not a detailed regulatory analysis is required under E.O. 12291. There are three principal review criteria to aid in this determination. They are:

1. If additional annualized costs of compliance, including capital charges (interest and depreciation), total $100 million (i) within any one of the first five years of implementation, or (ii) if applicable, within any calendar year up to the date by which the law requires attainment of the relevant pollution standard.
2. If a major increase in the selling price of the product results for consumers, individual industries, Federal, State or local government agencies, or geographic regions, or
3. If significant adverse effects on competition, investment, productivity, employment, innovation, or the ability of U.S. firms to compete with foreign firms results.

The macroeconomic impact from the proposed regulatory alternatives would not be significant enough to meet any one of the above criteria for the determination of major economic impact. The expected worst case maximum price impact of .047 percent increase is well below a major criterion. Table 9-22 presents the estimated total fifth year annualized costs (really savings) of compliance given the following assumptions:

1. Six new plants will be built as specified in Section 9.1.4.
2. All new plants will produce wall coverings characterized by model plant C.

Due to significant positive recovery credits, the total additional annualized cost of control in the fifth year will be $-60,000 at the 75 percent level and $-126,000 at the 85 percent level. These results are summarized in Table 9-22. Finally, no major impacts are expected on geographical regions, local governments, competition, investment, productivity, and so on. Therefore, no significant macroeconomic impacts are likely.

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Appendix A - Evolution of the Background Information Document

The purpose of this study was to develop a basis for supporting proposed new source performance standards (NSPS) for the flexible vinyl coating and printing industry (FVC&P). To accomplish the objectives of this program technical data was acquired on the following aspects of the FVC&P industry: (1) web formation; (2) coating and printing operations (3) the release and controllability of organic emissions into the atmosphere by these sources; and (4) the types and costs of demonstrated emission control technologies. The bulk of this information was retrieved from the following sources:

- open technical literature
- meetings with specific companies, trade associations, and regulatory authorities
- plant visits
- emissions source testing.

In October, 1979, a literature search began with the automated bibliographic and direct type data bases available through Lockhead Retrieval Service's DIALOG and Systems Development Corporation's ORBIT. The data bases search included APTIC, *Chemical Abstracts*, *Engineering Index*, NTIS, ENVIROLINE, and Predicast's EIS Plants. The information found in the literature helped in developing an understanding of the vinyl coating industry and the processes used. But there was very little factual information as to the quantity or type of pollutants emitted by the industry.

The following chronology of events lists the major activities undertaken in gathering data and information to support the proposed standard.

September 28, 1979	Visited Uniroyal, Inc. 312 North Hill Street Mishawaka, Indiana 46544
October 1979	Telephone survey of industry
November 1979	Telephone survey of State agencies
November 7, 1979	Visited General Tire and Rubber Company Columbus, Mississippi
December 2, 1979	Visited General Tire and Rubber Company Coated Fabrics Company Reading Division General Street Reading, Massachusetts 01867
December 12, 1979	Visited Stauffer Chemical Company Anderson, South Carolina 29623
January 1980	Section 114 Letters sent to selected companies within flexible vinyl coating industry and vinyl flooring industry
February 27, 1980	Visited General Tire and Rubber Company Coated Fabrics Company Reading Division Reading, Mass. 01867
March 5, 1980	Visited Standard Coated Products Department of American Cyanamid Company Now Division of L. F. Carpenter & Co. Humboldt Industrial Park P.O. Box D Hazelton, Pa. 18201
March 27, 1980	Visited Pervell Industries, Inc. Plainfield, Connecticut 06374
April 14, 1980	Visited Compo Industries, Inc. Bradford Division 200 Market Street Lowell, Mass. 01852
April 17, 1980	Visited Armstrong Cork Company Lancaster Floor Plant Lancaster, Pennsylvania 17604

April, 1980	Flooring industry was excluded from this NSPS
April 24, 1980	Visited Athol Manufacturing Corporation P.O. Box 105 Butner, North Carolina 27509
July 30, 1980	Visited Stauffer Chemical Company Anderson, South Carolina 29623
August 6, 1980	Visited Firestone Plastics Company Salisbury, Maryland
August 1980	Emissions from the vinyl web preparatory processes were excluded from this NSPS.
September 29 through October 3, 1980	Visited General Tire and Rubber Company Coated Fabrics Company Reading Division General Street Reading, Mass. 01867 (Emission source testing)
December 1980	Visited General Tire and Rubber Company Coated Fabrics Company Reading Division General Street Reading, Mass. 01867
February 1980	EPA Project team met with a representative of the Chemical Film and Fabric Association and several members of the FVC&P Industry.
February 1980	Embossers were excluded from the FVC&P NSPS.
March 18 through March 26, 1981	Visited General Tire and Rubber Company Coated Fabrics Company Reading Division General Street Reading, Mass. 01867 (Emission source testing)
July 1981	BID sent to 24 Industry members for early review.

APPENDIX B

INDEX TO ENVIRONMENTAL CONSIDERATIONS

This appendix consists of a reference system which is cross indexed with the October 21, 1974, Federal Register (39 FR 37419) containing EPA guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

APPENDIX B

CROSS-INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
1. Background and Summary of Regulatory Alternatives	The regulatory alternatives from which standards will be chosen for proposal are summarized in Chapter 1, Section 1.1.
Statutory Basis for the Standard	The statutory basis for proposing standards is summarized in Chapter 2, Section 2.1.
Industry Affected	A description of the industry to be affected is given in Chapter 3, Section 3.1.
Process Affected	A description of the process to be affected is given in Chapter 3, Section 3.2.
Availability of Control Technology	Information on the availability of control technology is given in Chapter 4.
Existing Regulations at State or Local Level	A discussion of existing regulations for the industry to be affected by the standards are included in Chapter 3, Section 3.3.
2. Environmental, Energy, and Economic Impacts of Regulatory Alternatives	
Health and Welfare Impact	The impact of emission control systems on health and welfare is considered in Chapter 7, Section 7.1.

Continued

CROSS-INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (Concluded)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
Air Pollution	The air pollution impact of the regulatory alternatives are considered in Chapter 7, Section 7.1.
Water Pollution	The impacts of the regulatory alternatives on water pollution are considered in Chapter 7, Section 7.2.
Solid Waste Disposal	The impact of the regulatory alternatives on solid waste disposal are considered in Chapter 7, Section 7.3.
Energy	The impacts of the regulatory alternatives on energy use are considered in Chapter 7, Section 7.4.
Costs	The cost impact of the emission control systems is considered in Chapter 8, Section 8.1.
Economics	Economic impacts of the regulatory alternatives are considered in Chapter 9, Section 9.2.

APPENDIX C

EMISSION SOURCE TEST DATA

In order to obtain emission data on a controlled plant in the flexible vinyl printing (FVC&P) industry, a testing program was conducted. The results of the program provide support for a new source performance standard (NSPS) for FVC&P industry.

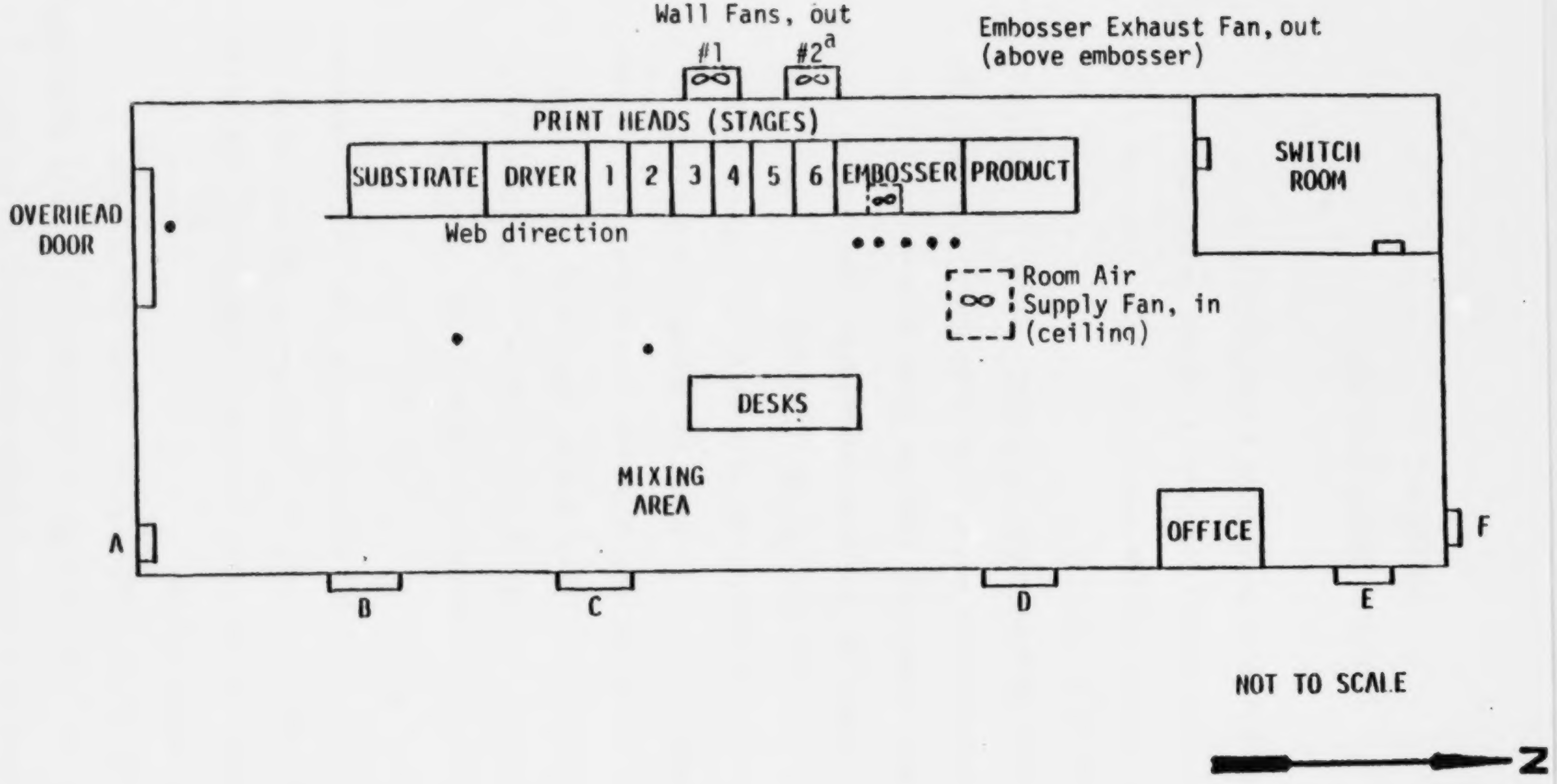
The General Tire and Rubber Company plant, located at 1 General Street, Reading, Massachusetts was the test site during the weeks of September 30, through October 10, 1980 and later in March 1981. The plant occupies a single floor building and produces vinyl coated fabric for automotive, marine, wallcovering and industrial end uses. A new, six station, Baker Perkins print line, with an inline embosser, had recently been brought on stream to print and emboss wallcovering.

The print line tested by EPA, is housed in a separate room in the plant. The print room's ventilation system consists of a wall exhaust fan, a room air supply fan, a carbon adsorption inlet fan, an embosser exhaust fan and several open doorways. Figure C-1 is a graphical representation of the room.

The print line VOC emissions are captured by a hooding system that directs the captured emissions into the individual print head ovens. The capture emissions from the print line are controlled by a Sutcliffe Speakman carbon adsorption system.

C.1 GENERAL TIRE AND RUBBER COMPANY PLANT - First Test Program

The purpose of the first test was to determine the capture efficiency of the print line based on a comparison between the mass of solvent


Wall Fans, out
#1
#2[a]
Embosser Exhaust Fan, out
(above embosser)
PRINT HEADS (STAGES)
SUBSTRATE
DRYER
1
2
3
4
5
6
EMBOSSER
PRODUCT
SWITCH ROOM
OVERHEAD DOOR
Web direction
Room Air Supply Fan, in (ceiling)
DESKS
MIXING AREA
OFFICE
A
B
C
D
E
F
NOT TO SCALE
N

- Ambient VOC Measurement Locations for VOC Measurement in Figure C-3

Figure C-1. GTR Print Room.

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a. #2 wall fan was not used during the GTR test applied at the print line and the mass of gaseous VOC emissions ducted to the adsorber. In order to make this comparison, a material balance between liquid VOC input and gaseous VOC output was required. In order for the results to be meaningful, closure of a material balance around the print line was necessary.

VOC measurements were made on a continuous basis at the wall fan exhaust, embosser exhaust and carbon adsorber inlet. Ink usage was determined by measuring changes in the level of the ink tanks supplying the print line. Ink samples were obtained during each run from each of the print stations applying ink and later analyzed for solvent content. Product samples were also obtained for solvent retention analysis.

The 35,000 SCFM room air supply fan was large enough to supply outside air to the print room when three print lines were installed. During the test, only one print line was housed in the print room and the room air supply fan was on. Lack of proper air distribution caused most of the flow from this fan to be directed down through the print line. Approximately 15,000 SCFM were exhausted from the print room through the carbon adsorber, wall exhaust fan, and embosser. The balance, 20,000 SCFM, was exhausted through open doors. During the test the large air flow from the room air supply fan caused excessive turbulence around the print stations. Results indicated that capture efficiency had been affected and was much less than design expectations. Also closure of the material balance, based on liquid VOC in and gaseous VOC out, was not achieved.

C.2 GENERAL TIRE AND RUBBER COMPANY - Second Test Program

The General Tire and Rubber Company was revisited for further testing March 18-26, 1981. The testing approach was modified from the first test in two very important ways. Unlike the first test which based capture efficiency on liquid and gaseous VOC measurements, this test required only gaseous VOC measurements. Secondly, the retest was conducted with the room air supply fan off to improve air management around the print line. In addition, doors to rooms with other solvent sources were closed to prevent VOC leakage into or out of the print room from other areas of the plant.

The test program consisted of two phases: Phase 1, determination of capture efficiency and Phase 2, determination of carbon adsorption control device efficiency.

During Phase 1, emissions were measured continuously at three sites: carbon adsorber inlet, wall fan exhaust, and embosser exhaust. During the first few days of testing, preliminary data indicated the wall exhaust fan disrupted air distribution much like the room air supply fan during the 1980 test. Therefore, plant management agreed to limit the use of this fan during the test days, to periods when the print head fans were off. The print line was always down during such periods.

Periodic measurements at the embosser air intake were taken to determine the ambient room VOC emissions that were exhausted through the embosser exhaust fan. Because the embosser is not part of the affected facility, any emissions generated within the embosser are not considered under the vinyl NSPS. The embosser generated emissions along with the print line room ambient VOC emissions are both exhausted through the embosser exhaust fan, therefore, these ambient VOC emissions must be quantified to determine capture efficiency. Since there is very little data characterizing embosser VOC emissions, VOC measurements were also taken at the embosser exhaust to further characterize these emissions.

During Phase 2, VOC measurements were made at both the inlet and outlet to the carbon adsorber. Ambient VOC concentrations around the embosser inlet were continued to obtain further data on capture efficiency.

During both phases of the test, ambient VOC concentrations throughout the print room were monitored. Threshold Limit Values (TLV-TWA) were not exceeded.

C.3 SUMMARY OF RESULTS

A summary of the capture efficiency results obtained during the 1981 GTR test is shown in Table C-1. Capture efficiency was calculated by comparing the VOC emissions directed to the carbon adsorption system with the ambient room VOC emissions exhausted through the embosser. The longest continuous run for a product, lasting at least thirty minutes but not more than three hours, was designated as a test run. It was desired to keep the test run of reasonably short duration since the printing periods are frequently short due to planned and unplanned interruptions. A sufficient period of time is needed to allow the print line to reach reasonably steady state process conditions. Based on a general understanding of the printing equipment and process, a minimum thirty minute test run was selected.

TABLE C-1. SUMMARY OF CAPTURE EFFICIENCY DATA FROM 1981 GTR TEST

Date	Production Order Number	Run Time Start	Run Time End	Run Length (minutes)	VOC Emissions (Kg) Embosser Air Intake	VOC Emissions (Kg) Wall Fan	VOC Emissions (Kg) CA Inlet	Capture Efficiency[a] (%)
3/18/81	T-14582	1401	1607	126	4.8	0[b]	66.4	93
3/19/81	T-15523	1420	1610	110	3.2	6.9	21.6	NM[c]
3/20/81	T-15521	1256	1402	74	2.9	0[b]	27.0	90
3/23/81	T-15516	0909	1025	76	2.3	0[b]	22.3	91
	T-15519	1351	1413	32	0.6	0[b]	6.0	91
3/25/81	T-15511	0942	1047	65	2.5	0[b]	35.5	94
3/26/81	T-15508	1126	1222	56	1.7	0[b]	21.6	93
	T-15507	1439	1540	61	1.6	0[b]	21.5	93

[a] Capture Efficiency (%) = $\frac{\text{CA Inlet Emissions (kg)}}{\text{Embosser Air Intake Emission (kg)} + \text{CA Inlet Emissions (kg)}}(100\%)$

[b] Wall fan not operating properly.

[c] Not meaningful because of poor air management during this test run.

In order to measure ambient VOC drawn into the embosser air intake, ambient concentration measurements around the embosser were made periodically during each test day. Embosser air intake emissions values are based on the average concentration measurements taken during each test run. The capture efficiencies for the eight test runs ranged from 90 percent to 95 percent and averaged 92 percent.

A summary of the carbon adsorption control device efficiency data from the 1981 GTR test is presented in Table C-2. Again, a test run was designated as the longest continuous run, lasting at least 30 minutes but not more than 3 hours, for each product. Carbon adsorption control device efficiencies averaged 99 percent. However, the GTR adsorption system was not operating at design conditions during the 1981 test. The system, which had been on stream for only a week prior to the test, operated only eight hours a day. At the end of each day, the beds were regenerated twice to minimize the possibility of bed fires during the next day's start up. Therefore, these carbon adsorption efficiencies may be somewhat higher than would be expected under design conditions.

Table C-3 is a summary of the VOC measurements taken during the 1981 test. As mentioned earlier, the embosser exhaust emissions shown in Table C-3, include embosser generated emissions which are not subject to the NSPS.

Figure C-2 is a graphical presentation of ambient VOC data taken on March 18, 1981. Because the VOC vapors are heavier than air, it was thought that the vapors might accumulate near the print room floor. On March 18, 1981 ambient readings were taken throughout the print room at

TABLE C-2. SUMMARY OF CARBON ADSORPTION EFFICIENCY DATA FROM 1981 GTR TEST

Date	Production Order Number	Run Time		Run Length (minutes)	VOC Emissions (Kg)		Carbon Adsorption Efficiency
		Start	End		CA Inlet	CA Outlet	
3/25/81	T-15511	0942	1047	65	35.5	0.13	99.6
3/26/81	T-15508	1126	1222	56	21.5	0.32	98.5
	T-15507	1439	1540	61	21.5	0.22	99.0

Table C-3. Summary of VOC Measurement Data of Second GTR Test

Date	Production Order Number	Process Operations	Time Interval		Total Minutes	VOC Emissions (Pounds as MEK)			
			Start[a]	End		Embosser	Wall Fan	CA Inlet	Total
3-18-81	T-14582	Preparation	0915	1035	80	NM	0	2.57	
		Leader Threading	1035	1043	8	0.15	0	0.60	0.75
		Color Matching	1043	1401	198	39.20	0	76.5	115.7
		1000 Yards Printing	1401	1423	22	2.74	0	34.8	37.5
		1000 Yards Printing	1423	1445	22	2.55	0	23.5	26.0
		1000 Yards Printing	1445	1507	22	2.32	0	24.4	26.7
		1000 Yards Printing	1507	1529	22	2.33	0	23.8	26.1
		1000 Yards Printing	1529	1551	22	2.49	0	23.2	25.7
		Completion of Run	1551	1607	16	1.73	0	16.5	18.2
		Threading New Leader	1607	1613	11	0.69	0	4.27	4.96
		Clean Up	1613	1618	5	0.58	0	3.56	4.14
		Clean Up	1618	1640	22	2.23	0	NM	
		TOTAL PRINT TIME	1401	1607	126	14.2	0	146.2	160.4
		TOTAL RUN TIME	1043	1613	330	54.0	0	230.5	281.0

NM: Not measured - analyzer problems or calibrations in progress.

[a] Start time for the initial time interval is the time when FID monitoring began that day.

Table C-3. Summary of VOC Measurement Data of Second GTR Test (Continued)

Date	Production Order Number	Process Operations	Time Interval Start[a]	Time Interval End	Total Minutes	VOC Emissions (Pounds as MEK) Embosser	Wall Fan	CA Inlet	Total
3-19-81	T-15626	Printing in Progress	0734	0848	74	8.53	0	NM	
		Printing	0848	0854	6	0.902	0	4.09	4.99
		Stop and Start	0854	0908	14	1.50	0	6.22	7.72
		1000 Yards Printing	0908	0930	22	2.65	0	8.36	11.0
		Stop and Start	0930	0945	15	0.781	0	3.04	13.8
		1000 Yards Printing	0945	1007	22	2.47	0	11.6	14.1
		TOTAL PRINT TIME	0848	1007	79	8.30	0	33.3	41.6
		TOTAL RUN TIME	0848	1007	79	8.30	0	33.3	41.6
	T-15523	Preparations for Next Run	1007	1230	143	2.49	0	7.28	9.77
		Color Matching	1230	1332	62	4.14	0	10.6	14.7
		Embosser Repairs. Wall Fan On	1332	1420	48	4.41	6.24	15.1	25.7
		1000 Yards Printing	1420	1442	22	4.05	2.43	9.22	15.7
		1000 Yards Printing	1442	1504	22	3.85	2.96	10.3	17.2
		1000 Yards Printing	1504	1526	22	3.99	3.20	10.0	17.2
		1000 Yards Printing	1526	1550	24	4.25	3.49	10.9	18.7
		Run Completed	1550	1610	20	3.58	3.14	7.09	13.8
		Clean Up	1610	1628	18	1.14	2.25	10.2	13.6
		Clean Up	1628	1632		0.18	0.48	NM	
		Clean Up	1632	1634		0.09	NM	NM	
		TOTAL PRINT TIME	1230	1610	220	28.3	21.5	73.2	123.0
		TOTAL RUN TIME	1420	1610	110	19.7	15.2	47.5	82.4

NM: Not measured - analyzer problems or calibrations in progress.

[a] Start time for the initial time interval is the time when FID monitoring began that day.

Table C-3. Summary of VOC Measurement Data of Second GTR Test (Continued)

Date	Production Order Number	Process Operations	Time Interval		Total Minutes	VOC Emissions (Pounds as MEK)			
			Start[a]	End		Embosser	Wall Fan	CA Inlet	Total
3-20-81	T-15521	Completing Previous Run	0740	0744	4	0.67	0	NM	
		Completing Previous Run	0744	0814	30	3.42	0	19.4	22.8
		Preparation for T-15521	0814	0958	104	4.56	0	14.7	19.3
		Color Matching	0958	1019	21	1.91	0	31.2	33.1
		Printing Start/Stop for Repairs	1019	1148	89	7.97	0	35.6	43.6
		Printing Embosser on	1148	1150	2	0.233	0	1.16	1.39
		1000 Yards Printing	1150	1212	22	4.32	0	18.2	22.5
		Printing Start/Stop for Repairs	1212	1256	44	6.76	0	29.5	36.3
		1000 Yards Printing	1256	1318	22	4.27	0	17.27	21.5
		1000 Yards Printing	1318	1340	22	4.25	0	17.6	21.8
		1000 Yards Printing	1340	1356	16	3.22	0	13.6	16.8
		Run Completed	1356	1410	14	2.41	0	10.91	13.3
		Cleaning Print Heads	1410	1426	16	2.09	0	7.49	9.58
		Clean Up	1426	1532	66	6.06	0	NM	
		TOTAL PRINT TIME	1019	1410	231	33.4	0	143.8	177.2
		TOTAL RUN TIME	0958	1410	252	35.3	0	175.0	210.3

NM: Not measured - analyzer problems or calibrations in progress.

[a] Start time for the initial time interval is the time when FID monitoring began that day.

Table C-3. Summary of VOC Measurement Data of Second GTR Test (Continued)

Date	Production Order Number	Process Operations	Time Interval		Total	VOC Emissions (Pounds as MEK)			
			Start[a]	End	Minutes	Embosser	Wall Fan	CA Inlet	Total
3-23-81	T-15516	Printing in Progress	0850	0909	19	1.92	Sampling	10.51	12.43
		1000 Yards Printing	0909	0931	22	2.60	Discontinued	13.06	15.7
		1000 Yards Printing	0931	0953	22	2.78		14.70	17.5
		1000 Yards Printing	0953	1015	23	3.12		14.20	17.3
		Run Completed	1015	1025	10	1.48		7.15	8.63
		TOTAL PRINT TIME	0850	1025	95	11.9		59.6	71.5
		TOTAL RUN TIME	0850	1025	95	11.9		59.6	71.5
	T-15519	Threading Leader	1025	1037	12	1.41		24.60	26.0
		Cleaning. PH Fans off. Wall Fan on	1037	1239	122	5.25		4.17	9.42
		Color Matching, Web Alignment	1239	1244	5	0.070		0.180	0.250
		Wall Fan Off. Color Matching	1244	1324	40	0.85		10.3	11.2
		Printing Line Down Once	1324	1351	27	1.88		9.90	11.8
		1000 Yards Printing	1351	1413	22	1.56		9.02	10.6
		Line Up and Down. Trimming Problems	1413	1605	112	6.71		40.0	46.7
		Problems Persist. Run Ended	1605	1628	23	1.14		10.5	11.6
		Repairs	1628	1633	5	0.27		1.16	1.43
		Repairs	1633	1636	3	NM		1.93	
		TOTAL PRINT TIME	1324	1605	161	10.2		58.9	69.1
		TOTAL RUN TIME	1239	1628	229	12.2		69.6	81.8

NM: Not measured - analyzer problems or calibrations in progress.

[a] Start time for the initial time interval is the time when FID monitoring began that day.

Table C-3. Summary of VOC Measurement Data of Second GTR Test (Continued)

Date	Production Order No.	Process Operations	Time Interval Start[a]	Time Interval End	Total Minutes	VOC Emissions (Pounds As MEK) CA Inlet	VOC Emissions (Pounds As MEK) Ca Outlet	CA Unit Control Efficiency (%)[b]	Carbon Bed In Operation (Adsorbing)	Time of Bed Switch[c]
3-24-81		Embossing Entire Day								
3-25-81	T-15511	Color Matching	0859	0900	1	0.66	NM		3	
		Printing in Progress	0900	0922	22	20.1	NM		3	
		Printing	0922	0942	20	21.8	0.048	99.8	1	0922*
		1000 Yards Printing	0942	1003	21	53.5	0.071	99.9	1	
		1000 Yards Printing	1003	1020	17	21.2	0.067	99.7	1	
		1000 Yards Printing	1020	1037	17	22.7	0.093	99.6	3	
		Run Completed	1037	1047	10	10.7	0.065	99.4	3	
		Leader Threading	1047	1108	21	15.7	0.114	99.3	3	
		Wall Fan on Preparation For Next Run	1108	1217	69	7.69	0.317	95.9	3/1	1117**
		Wall Fan on Preparation For Next Run	1217	1230	13	NM	0.053		3	
		TOTAL PRINT TIME	0922	1047	85	130	0.344	99.7		
		TOTAL RUN TIME	0922	1108	106	146	0.458	99.7		

*Beginning time of 0922 was estimated, based on observed end time of 1020

**Bed No. 1 began adsorbing 1117 and continued to 1217.

[a] Start time for the initial time interval is the time when FID monitoring began that day.

[b] 100 [1-(OUTLET/INLET)]

[c] Nominal bed cycle (adsorption/desorption) is about 120 minutes.

Table C-3. Summary of VOC Measurement Data of Second GTR Test (Continued)

Date	Production Order No.	Process Operations	Time Interval Start[a]	Time Interval End	Total Minutes	VOC Emissions (Pounds As MEK) CA Inlet	VOC Emissions (Pounds As MEK) Ca Outlet	CA Unit Control Efficiency (%)[b]	Carbon Bed In Operation (Adsorbing)	Time of Bed Switch[c]
3-26-81	T-15508	Preparation	0856	0936	40	NM	0.194			
		Preparation	0936	0939	3	0.880	0.036	95.9	1/3	0928
		Color Matching	0939	1059	80	37.0	1.26	96.6	3	
		Printing	1059	1126	27	21.1	0.356	98.3	3/1	1028
		100 Yards Printing	1126	1151	25	20.7	0.313	98.5	1	
		100 Yards Printing	1151	1216	25	21.6	0.313	98.6	1/3	1128
		Run Completed	1216	1222	4	5.15	0.072	98.6	3	
		Embosser off. Clean up	1222	1229	7	5.11	0.156	96.9	3	
									3	
		TOTAL PRINT TIME	1059	1222	83	72.6	1.05	98.6		
		TOTAL RUN TIME	0939	1229	163	110.7	2.47	97.8		
	T-15507	Preparation	1229	1326	57	28.8	0.508	98.0	3/1	1233
		Color Matching	1326	1420	54	31.6	0.438	98.6	1/3	1334
		Printing. Line Down Once	1420	1439	19	13.8	0.158	98.9	3/1	1435
		1000 Yards Printing	1439	1501	22	16.9	0.211	98.8	1	
		1000 Yards Printing	1501	1523	22	17.7	0.160	99.1	1	
		Run Completed	1523	1540	17	12.8	0.116	99.1	1/3	1534
		Line Down. Preparation for next run	1540	1612	32	15.0	0.217	98.6	3	
		Line Down. Preparation for next run	1612	1614	2	NM	0.014		3	
		TOTAL RUN TIME	1420	1540	80	61.2	0.645	98.9		
		TOTAL RUN TIME	1326	1540	134	92.8	1.08	98.8		

[a] Start time for the initial time interval is the time when FID monitoring began that day.

[b] 100 [1-(OUTLET/INLET)]

[c] Nominal bed cycle (adsorption/desorption) is about 120 minutes.

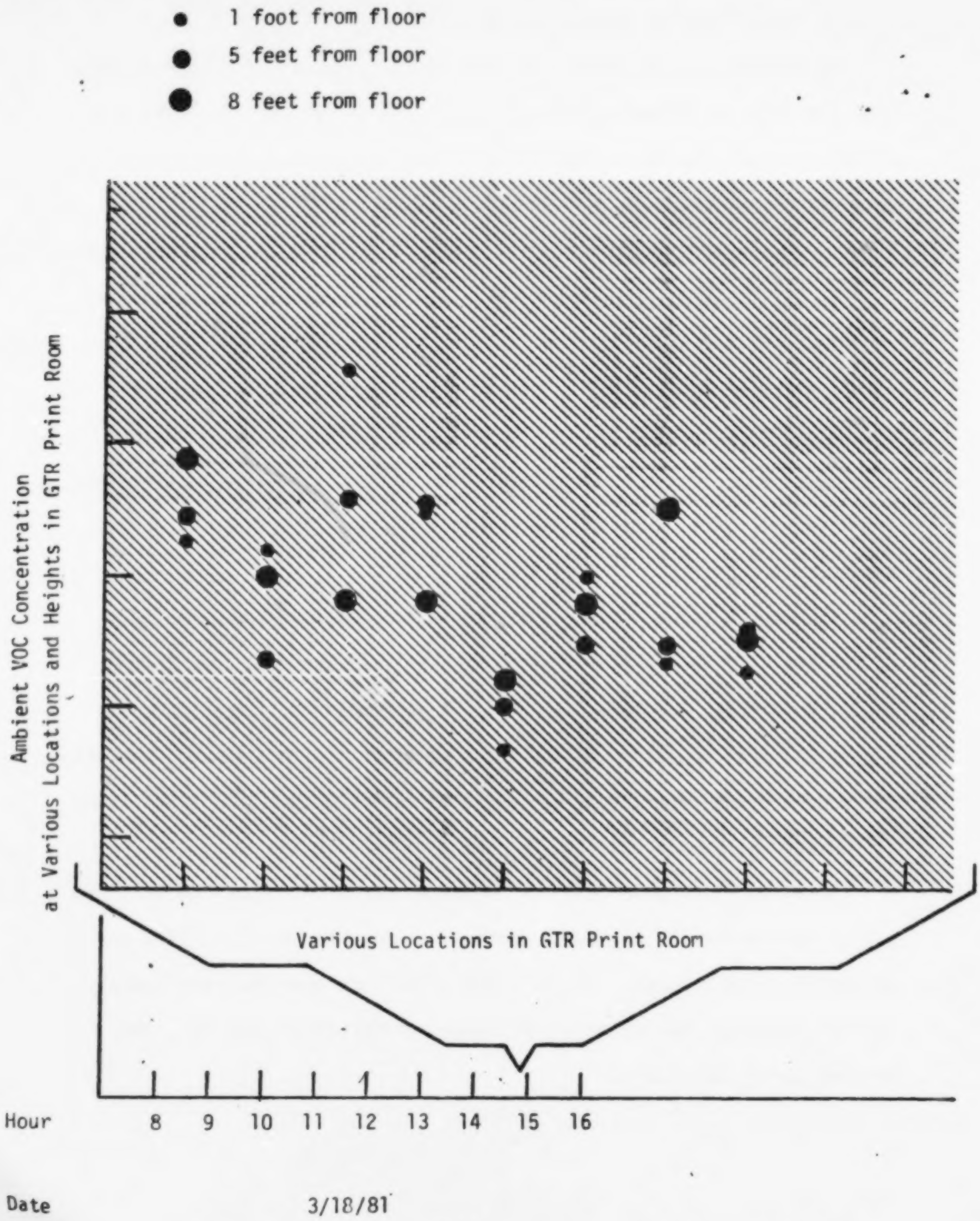
1 foot, 5 feet and 8 feet from the floor. As demonstrated in Figure C-2, no stratification occurred within the room.

As previously discussed, the operation of the wall fan, during the 1981 GTR test, affected capture efficiency of the print line. The use of this fan was therefore limited to periods when the print head fans were off. When the wall fan was off, a slight reduction in air flow occurred. The air flow decreased from 13,300 SCFM (wall fan plus embosser fan) to 11,700 SCFM (print head fans plus embosser fan). If, with the wall fan off, the ventilation of the print room were insufficient, then accumulation of ambient VOC in the print room would occur. Any such accumulations occurring during the test runs would affect the capture efficiency calculations. Also, any accumulation might lead to exceeding the Threshold Limit Value - Time Weighted Average (TLV-TWA) for worker exposure to solvents.

Figure C-3 shows a portion of the ambient VOC measurements taken during the 1981 test program. These ambient measurements seen in the figure were taken in the locations shown in Figure C-1. Also shown in Figure C-3 are the test runs and the times when the wall fan was operating. The double lines separating the test days represent non-test times, such as weekend and evening shifts, for which no information is available.

Referring to Figure C-3, testing began on March 18th. The wall fan was on throughout the day but because of a loose fan belt, no flow was measured at its exhaust. At 14:01 the print line operated continuously for 126 minutes. During this continuous run period or test run, one ambient survey was taken.

Figure C-2. Ambient VOC Concentration Data for 3/18/81



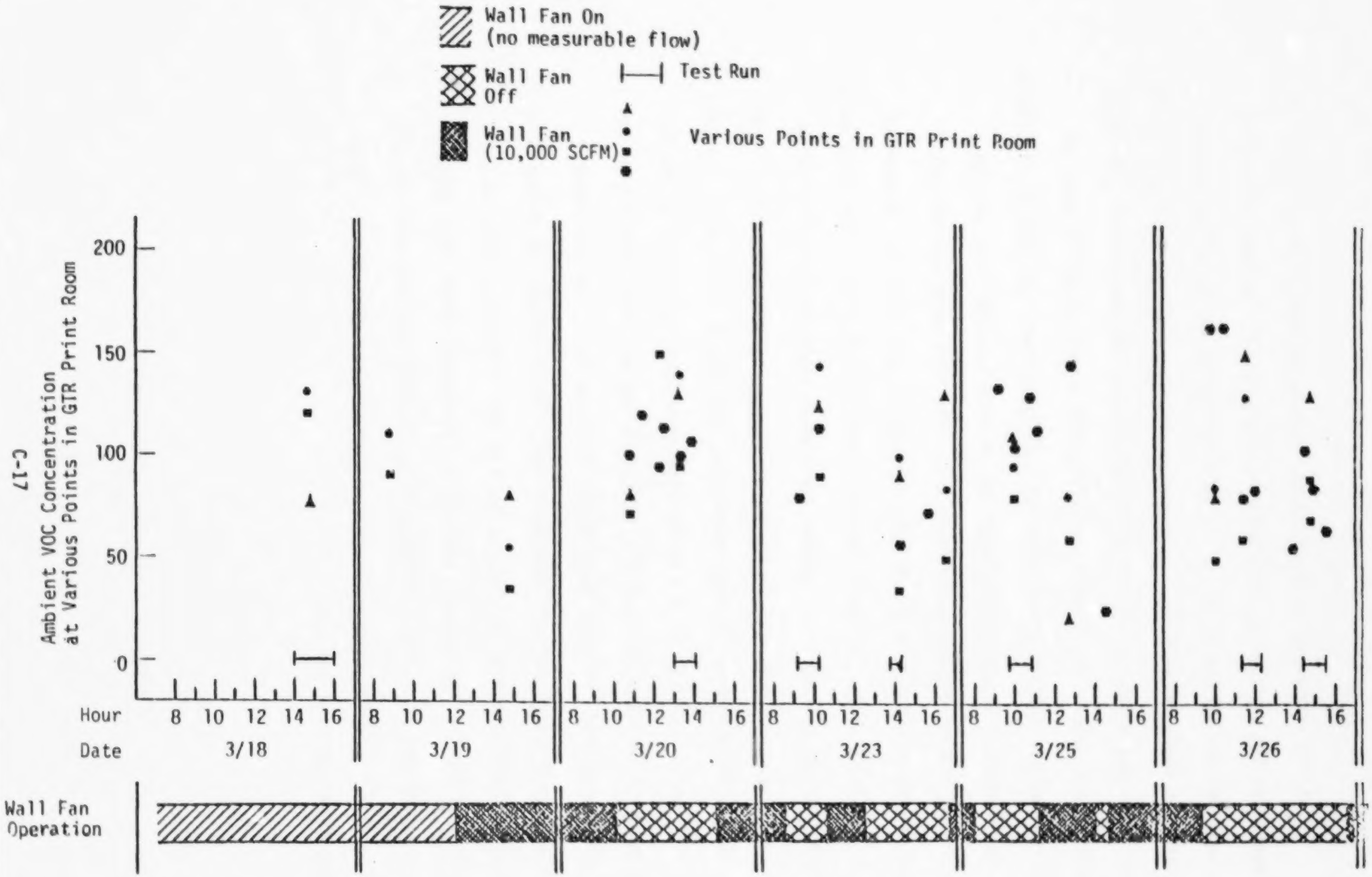


Figure C-3. Ambient VOC Concentration Data for 1981 GTR Test.

Testing continued on March 19th. In the morning, the wall fan was operating but no flow was measured at its exhaust. No test runs were completed during the morning. An ambient survey of the print room was taken at approximately 9:00. At approximately 12:00 the fan belt of the wall fan was adjusted and the wall fan exhaust increased to 10,000 SCFM. This large volume of air was exhausted from almost directly over the print heads. The effect of this poor air management on capture efficiency was dramatic. Capture efficiency was at once reduced below design expectations as evidenced in Table C-1. The test data was not valid during the afternoon of March 19th because of this poor air management.

On March 20th, the wall fan was turned off at 9:55. Test data were taken throughout the day. Ambient data were taken periodically while the wall fan was off. At 12:56 the print line operated continously for seventy-four minutes, thereby completing the second test run of the 1981 test program. At 14:52, the print line went down for cleaning and the print head fans were turned off. The wall fan was then turned back on.

On the next two test days, March 23rd and 25th, two different colors or patterns were printed each day. These changes in patterns or colors required the print line as well as the print head fans to be turned off while the changes were made. Therefore these test days, March 23rd and 25th, were interrupted by periods when the wall fan was on. Only a limited amount of ambient data is available for the test runs of March 23rd and 25th.

The final test day, March 26th, proceeded much like March 20th. Two test runs were completed and ambient data were taken periodically throughout the test day.

On both March 20th and 26th, there was a long continuous period of time when the wall fan was off. Several ambient surveys were conducted during these long periods. The results demonstrate that no noticeable or significant build-up of VOC occurred in the print room. On the other test days (March 18, 19, 23, and 25) only a few ambient surveys were conducted, or the wall fan was turned on in between production runs. Thus, alone, the data from these days (March 18, 19, 23, and 25) are inconclusive in assessing a build-up of VOC in the print room. However, the ambient levels on these days are similar to the levels on March 20th and 26th, thus it is assumed that the ventilation system was operating in the same manner and no accumulation occurred during these days (March 18, 19, 23 and 25).

Table C-4 contains a summary of the data obtained from the first GTR test. As stated previously, the purpose of the test was to determine capture efficiency based on the ratio of the mass of gaseous VOC sent to the carbon adsorber to the mass of liquid VOC applied at the print line. It was very difficult to accurately characterize the net mass flow of solvent to the print head and the material balance between the liquid VOC in and gaseous VOC out could not be closed. Also the mass flow of solvent through the doorways was higher than expected due to the room air supply fan. The test results were inconclusive and therefore no data analysis is presented.

TABLE C-4. SUMMARY OF DATA FROM FIRST GTR TEST[1]

Date	Production Order Number	Time		Liquid VOC Applied (kg)	Gaseous VOC Emissions (kg)				VOC Retained in Product (kg)
		Start	End		Carbon Adsorber Inlet	Wall Fan	Embosser Exhaust	Door[2] Fugitives	
9/30/80	T-178	0924	1836	143.7	98.2	13.8	16.8	16.8	ND[5]
10/1/80	T-164	0945	1709	202.0	140.9	14.2	8.1	13.6	2.4
10/2/80	T-169	0745	1342	214.6	142.6	16.2	15.1	9.7	1.1
	T-152	1342	1728	166.6	84.6	8.0	6.4	6.4	2.3
10/3/80	T-131	0914	1406	96.8	47.1	8.9	6.6	7.9	0.6
10/6/80	T-196	1140	1805	146.4	100.5	11.1	18.9	11.8	2.3
10/7/80	T-200	1101	1413	121.2	57.4	4.1	12.7	4.4	1.9
10/8/80	T-203	0955	1503	133.9	65.1	7.6	13.5	9.9	ND[5]
10/9/80	MEK	1016	1202	12.3	10.6	3.9	0.8[3]	0[4]	0.2
10/10/80	T-232	1318	1552	47.9	30.4	6.1	1.5[3]	0[4]	1.3

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[1] Air from a supply fan, designed to supply air for 3 print lines, was directed down through the print stations. This poor air distribution disturbed air management around the print heads. Capture efficiency during these tests is not meaningful and is not presented.

[2] These figures are based on estimated air flows and ambient VOC concentrations in the process room.

[3] Embosser heat was off.

[4] Room air supply fan was turned off.

[5] No data.

APPENDIX D - EMISSION TESTING AND MONITORING

D.1 PERFORMANCE TEST METHODS

For the standard for the flexible vinyl coating and printing (FVC&P) industry, performance test methods and procedures are needed in two areas: determination of the organic solvent content of the ink or coating, and determination of the overall control efficiency of the add-on pollution control system.

D.1.1 Analysis of Inks

1.1.1 Volatile Organic Compound Content of the Ink. The organic content of the ink may be obtained either from the ink manufacturer's formulation or from Reference Method 24, "Determination of Volatile Matter Content, Water Content, Density, Volume Solids, and Weight Solids of Surface Coatings." This method combines several American Society of Testing and Materials (ASTM) standard methods to determine the volatile matter content, density, volume of solids, and water content of the inks and related surface coatings.

If the FVC&P emission limit is in units of mass of volatile organic compound (VOC) per mass of ink solids, only portions of Reference Method 24 need to be used. For non-aqueous inks, the procedure to be used is ASTM D 2369-81, "Provisional Test Method for Volatile Content of Paints." For aqueous inks, the previously mentioned procedure (ASTM D 2369-81) is combined with a second procedure which determines the water content of the inks. There are two acceptable procedures for this: (1) ASTM D 3792-80, "Standard Test Method for Water in Water Reducible Paint by Direct Injection into a Gas Chromatograph," and (2) ASTM "Provisional Test Method for Water in Paint or Related Coatings by the Karl Fischer Titration Method." The results from these procedures are the non-aqueous volatile content of the ink (as a weight fraction) and the water content (as a weight fraction). The weight fraction solids content in the ink is then easily determined from these results by subtraction. The VOC content in the ink, in units of mass of VOC per mass of ink solids, is determined by dividing the weight fraction of non-aqueous volatiles by the weight fraction of solids.

The estimated cost of analysis per ink sample is $50 for the total volatile content procedure (ASTM D 2369-81). For aqueous inks, an additional $100 per sample is required for water content determination. Because the testing equipment is standard laboratory apparatus, no additional purchasing costs are expected.

D.1.1.2 Density of the Ink. The density of the ink may need to be determined in some cases. This value may be obtained either from the ink manufacturer's formulation or from a procedure in Reference Method 24. The procedure to be used is ASTM D 1475-60, "Standard Test Method for Density of Paint, Varnish, Lacquer, and Related Products."

The estimated cost of analysis per ink sample is $25. Because the testing equipment is standard laboratory apparatus, no additional purchasing costs are expected.

D.1.1.3 Sampling of Inks. For Method 24 analysis of an ink, a 1-liter ink sample should be obtained and placed in a 1-liter container. The head-space in the container should be as small as possible so that organics in the ink do not evaporate and escape detection. The ink sample should be taken at a place that is representative of the ink being applied. Alternatively, the ink may be sampled in the mixing or storage area while separate records are kept of dilution solvent being added at the print heads.

D.1.1.4 Weighted Average VOC Content. If a FVC&P plant uses all low-solvent inks, then each ink simply needs to be analyzed as described in Section 1.1.1. If the VOC content of each ink is below the standard, calculation of a weighted average is not needed. However, if a plant uses a combination of low and high-solvent inks, the weighted average VOC content of all the inks used over a specified time period needs to be determined. This is essentially a mass weighted average; thus, in addition to the Method 24 (or manufacturer's formulation) information, the amount (weight) of each ink used must be determined. Most plants already keep detailed records of amounts of inks used. Thus, it is expected that no additional effort will be needed to determine ink usage. If a plant keeps its inventory records on a volume basis, then the density of the ink (Section 1.1.2) needs to be determined to put the inventory on a mass basis.

D.1.2 Overall Control Efficiency

Performance test methods and procedures are used to determine the overall control efficiency of the add-on pollution control system. The add-on control system is composed of two parts: a vapor capture system, and a vapor processing device (carbon adsorber or incinerator). The control efficiency of each component is determined separately and the overall control efficiency is the product of the capture system and processing device efficiencies.

The performance test procedure in the proposed regulation defines the test length and the conditions under which testing is acceptable, as well as the way the reference test method measurements are combined to attain the final result.

D.1.2.1 Processing Device Efficiency. Two types of processing devices are expected in the FVC&P industry: carbon adsorbers and incinerators. The test procedure to determine efficiency is the same for each control technology.

To determine the efficiency of the emission processing device, the VOC mass flow in the inlet and outlet gas streams must be determined. The recommended test procedure for determining the mass of VOC in a gas stream combines several standard methods, EPA Reference Methods 1, 2, 3, 4, and proposed Method 25A. These methods and the reason for their selection are discussed later.

D.1.2.2 Capture System Efficiency. The efficiency of the vapor capture system is defined as the ratio of the mass of gaseous VOC emission from the flexible vinyl printing line. In order to determine the total mass of VOC emitted from a line, all fugitive VOC emissions from the printing area must be captured and vented through stacks suitable for testing. A total enclosure around the print line is needed to direct all other fugitive VOC emissions through suitable testing stacks. If a permanent total enclosure or its equivalent exists on the line prior to the performance test and the enclosure is capturing all fugitive emissions, the construction of a temporary enclosure would not be necessary. Otherwise, prior to the performance test, a temporary total enclosure would need to be constructed around the print line for the purpose of containing fugitive VOC emissions. In both cases, all doors and other openings through which fugitive VOC emissions might escape should be closed or properly vented to stacks suitable for testing.

If an embosser is operated in the print line, the performance test would be conducted either with the embosser heat turned off and the embosser exhaust tested in the same manner as a room exhaust stack or by separating the embosser from the print line by a total enclosure around the print line. An alternative to isolating embosser would be to provide a VOC allowance in the regulation to account for embosser emissions.

The mass flow of VOC in each applicable vent is determined by Reference Methods 1, 2, 3, 4, and 25A.

D.1.2.3 Time and Cost. It is recommended that the performance test consist of three runs. Each run may last from 1/2 to 3 hours for a total of 1-1/2 to 9 hours of actual data gathering. However, print line operations are intermittent; there are often long time periods between print runs for cleanup, setup, and color matching, so the total length of the performance testing varies. It is estimated, that for most operations, the field testing could probably be completed in 2 days (i.e., two 8-hour work shifts) with an extra day for setup, instrument preparation, and cleanup.

The cost of the testing varies with the number of sites to be tested: inlet, outlet, and fugitive vents. The cost is estimated at $6,000 per test site.

D.1.2.4 Details on VOC Concentration Measurement Method. The recommended VOC measurement method is proposed Reference Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer," (proposed in the Federal Register on December 17, 1980). This method was selected because it measures the expected solvent emissions accurately, is practical for long-term, intermittent testing, and provides a continuous record of VOC concentration. A continuous record is necessary because of print line and control device fluctuations. Measurements that are not continuous would not give a representative indication of emissions. The print lines in this industry operate intermittently, and the vent concentrations may vary significantly. Continuous measurements and records are easier to use for intermittent processes, and the short-term variations in concentration can be noted. The continuous records are averaged or integrated as necessary to obtain an average result for the measurement period.

Method 25A applies to the measurement of total gaseous organic concentration of vapors consisting of alkanes, and arenes (aromatic hydrocarbons). The instrument is calibrated in terms of propane or another appropriate organic compound. A sample is extracted from the source through a heated sample line and glass fiber filter and routed to a flame ionization analyzer (FIA). (Provisions are included for eliminating the heated sampling line and glass filter under some sampling conditions.) Results are reported as concentration equivalents of the calibration gas organic constituent or organic carbon.

Instrument calibration is based on a single reference compound. For this standard, propane is the recommended calibration compound. As a result, the sample concentration measurements are on the basis of that reference compound and not necessarily true hydrocarbon concentrations. The solvents commonly used in inks in this industry are methyl-ethyl ketone (MEK), methyl-iso-butyl ketone (MIBK), and toluene. MEK is the principle solvent. Because the industry uses solvent mixtures which vary from plant to plant, there is no standard solvent mixture to use for calibration.

Gas chromatograph (GC) analysis on bag samples was considered because results would be on the basis of true hydrocarbon concentrations. However, the GC/bag sample technique is not a continuous measurement and would be cumbersome and impractical because of the length of the testing. Furthermore, there is little advantage or extra accuracy gained from the GC approach. Propane was selected as the calibration gas species because it has close to a 1:1 response to MEK for an FIA. Thus measured concentrations are close to the true hydrocarbon concentrations.

The VOC analysis technique using an FIA measures total hydrocarbons including methane and ethane, which are considered nonphotochemically reactive, and thus not VOC's. Due to the ink solvent composition, little methane or ethane is expected in the gas streams; thus, chromatographic analysis is not needed nor recommended to adjust the hydrocarbon results to a nonmethane-nonethane basis.

Besides GC techniques, two other VOC concentration measurement methods were considered (and rejected) for this application: proposed Method 25B and Method 25.

Proposed Method 25B, "Determination of Total Gaseous Organic Concentration Using a Nondispersive Infrared Analyzer," (Federal Register, December 17, 1980) is identical to Method 25A except that a different instrument is used. Method 25B applies to the measurement of total gaseous organic concentration of vapor consisting primarily of alkanes. The sample is extracted as described in Method 25A and is analyzed with a nondispersive infrared analyzer (NDIR). Method 25B was not selected because NDIR analyzers do not respond as well as FIA's to the solvents used in this industry. Also, NDIR's are not sensitive in low concentration ranges (<50 ppm), and the outlet concentrations from incinerators and carbon adsorbers are often below 50 ppm.

Method 25, "Determination of Total Gaseous Nonmethane Organics Content" (TGNMO), was also considered. A 30- to 60-minute integrated sample is collected in a sample train, and the train is returned to the laboratory for analysis. The collected organics are converted in several analytical steps to methane and the number of carbon atoms is measured. Results are reported as organic carbon equivalent concentration. The TGNMO procedure is not recommended for the FVC&P standard because it is awkward to use for long test periods, and it does not continuously measure and record concentration. Concentration variations would be masked with a TGNMO time-integrated sample.

D.1.2.5 Details on Volume Measurement Method. Reference Methods 1, 2, 3, and 4 are recommended for determination of the volumetric flow rate of the gas streams. Reference Method 1 is used to select the sampling site, and Reference Method 2 measures the volumetric flow rate using a pitot tube velocity traverse technique. Methods 3 and 4 provide gas analysis and moisture content, which are used to determine the gas stream molecular weight in Method 2. The results are in units of standard cubic meters per hour. The results do not need to be adjusted to dry conditions (using Method 4 for moisture) because the VOC concentrations are measured in the gas stream under actual conditions. The VOC concentrations results from the FIA detector are reported as parts of VOC per million parts of actual (wet) volume (ppmv).

D.2 EMISSION MEASUREMENT TEST PROGRAM

During the standard support study for the FVC&P industry, the EPA conducted two source tests for VOC emissions at one plant. Testing for each test series occurred continuously during the daytime shift for 5 to 8 days.

D.2.1 Purpose of Test Program

Field testing was conducted to evaluate various testing approaches and methods, and to gather auxiliary useful information to understand better the process operation. The purpose of the testing program was to characterize not only the VOC emissions to the atmosphere, but the usage, end distribution, and material balance of the VOC/solvent throughout the entire printing process.

D.2.2 Comparison of the Two Test Series

The process operation was somewhat different for the two test series. During test series one, the carbon adsorber was not on line (although the carbon adsorber fans were operating); the wall exhaust fan and the embosser exhaust fan were both running; a ceiling makeup air/ventilation fan was operating; and several doorways to the print-room were open. During test series two, the carbon adsorber was on-line and operating; the wall exhaust fan and ceiling makeup air fan were turned off; the embosser exhaust fan was still operating; and all doorways to the room, except one, were closed. Thus, the air flow distribution in the printroom was different for the two test series. Other process operations and ambient conditions were similar for both test series.

The intent of the testing and the test procedures were also somewhat different for the two test series. For the first test series, VOC mass flow rate was determined at the carbon adsorber inlet, wall fan exhaust, and embosser exhaust. This provided information on VOC emissions to the atmosphere, and capture efficiency of the vapor control system. For the second test series, VOC mass flow rate was determined at the carbon adsorber inlet, carbon adsorber outlet, embosser exhaust, and embosser intake. This provided information on VOC emissions, carbon adsorber control efficiency, gaseous capture efficiency, and an estimate of the printroom VOC's that were drawn into the embosser. During both test series, ambient room concentration surveys and doorway flow surveys were made. These tests were much more detailed and frequent during the second test in order to get a firmer grasp on the air flow and VOC distribution in the printroom, and to ensure OSHA ambient VOC levels were not exceeded. A solvent material balance was tried during the first test only, relating solvent used to VOC emissions measured. This required monitoring ink and dilution solvent usage for each print run, as well as sampling and analyzing inks for organic content. On the other hand, in the second test, samples of wastewater and distillation column bottoms were taken from the carbon adsorber distillation/solvent recovery system and analyzed for solvents, providing information on the operation and efficiency of the solvent recovery system. Vinyl wall covering product samples were also obtained before and after the embosser and analyzed for solvent content, giving further information on the solvent material balance distribution and embosser operation.

D.2.3 The VOC Mass Flow Measurements

During the field tests, the VOC mass flow rate was determined at several gas stream vents: carbon adsorber inlet, carbon adsorber outlet, wall fan exhaust, and embosser exhaust. Both VOC concentration and volumetric flow rate were determined at each location. The vents were tested continuously each day during the daytime shift (except for the carbon adsorber outlet which was only tested for 2 days.)

Continuous VOC concentration was determined with a flame ionization detector according to proposed Method 25A. The instrument was calibrated to both propane and MEK each morning and evening, with span checks periodically during the day. Certified gas cylinders were used for propane standards; MEK standards were prepared in the field according to proposed Method 110. The response ratio of MEK versus propane was similar on all instruments. Independent propane and MEK audit cylinders were analyzed as a quality assurance check.

During the second test series, VOC concentrations were also measured (for part of the test period) with Reference Method 25 (TGNMO). Three 1-hour samples were taken at each test site. Duplicate trains were run in all cases. The Method 25 results were inconsistent and did not compare well with the Method 25A results, probably due to laboratory analysis problems.

Volumetric flow rate measurements were conducted at each test site two or three times per day. Method 1 was used to select the sampling location, and Method 2 to determine the flow rate. Gas analysis by Method 3 was not performed. Instead, the molecular weight of the vent gases was assumed to be the same as ambient air. This was a valid assumption since no combustion sources were involved and the hydrocarbon concentrations in the sampled streams were low. Moisture content was measured with a wet bulb/dry bulb instead of Method 4, but this should not significantly affect the results. Gas stream moisture for this process was not expected to differ from ambient. Also, moisture determination is not an important parameter in this test procedure. The moisture content is only used to adjust the molecular weight in a calculation step in Method 2; since actual volumes are used, the volumes do not need to be adjusted to a dry basis.

For this standard, Reference Methods 1, 2, 3, 4, and 25A are recommended for VOC mass flow measurements, and these methods or equivalent were followed during the field testing. Thus, the results can be used to support the standard.

D.2.4 Ambient Measurements

Ambient measurements were conducted during both test series, but more comprehensively during the second test. Open doorways were monitored periodically (∿3 times per day) to estimate the flux of VOC into and out of the printroom. The flow rate through the doorways was measured with a hand-held velometer (6 to 9 points were sampled per doorway). Concentration was measured with a portable combustible gas detector which was calibrated with MEK standard.

Ambient VOC concentration levels in the printroom were measured periodically during the test period. The surveys were conducted throughout the room at various heights (1', 5', 8' from floor).

Detailed, frequent surveys were made of the VOC concentration and flow rate into the embosser intake from the printroom, in order to estimate and characterize the print line fugitive VOC's which were drawn into the embosser exhaust stack. The VOC concentration and flow measurements were made at representative sites around the perimeter of the embosser intake hood as close to the intake as the physical equipment setup permitted.

Eight-hour exposure sampling was performed on 3 days at four locations in the printroom. Following a NIOSH ambient sampling procedure, ambient air samples were drawn through carbon tubes. Analysis consisted of extraction in carbon disulfide and liquid analysis by gas chromatograph. The MEK, MIBK, and toluene were measured.

D.2.5 Wastewater Samples

Wastewater samples from the carbon adsorption/distillation system were collected periodically for 2 days. The water samples were analyzed for MEK, MIBK, toulene, and total organic carbon using standard water analysis laboratory procedures.

D.2.6 Product Samples

Product samples of the vinyl wall covering were obtained before and after the embosser and analyzed for solvent content. The analysis procedure was an adaptation of NIOSH ambient carbon tube measurement techniques. The product samples were put in a container and air was drawn across them and then through a carbon tube, which collected the organics. The carbon tubes were analyzed in the same manner as the ambient sample carbon tubes, for MEK, MIBK, and toluene. The product sampling and analysis was a preliminary procedure. The results were in a lower range than expected, but there is no way to independently verify the results.

D.2.7 Liquid Solvent Usage Measurement

During the first test series, a liquid material balance test approach was attempted. The purpose of this part of the testing was to determine the total amount of solvent used for each print run and to compare it to the gaseous emissions that were measured.

All ink drums were weighed before and after the print run. Also, during the run, the ink level in the print-head tanks was monitored periodically with a dip stick. Ink samples were collected before and after each run and analyzed for solvent content according to Reference Method 24. Plant records and formulation data were also used as a cross check. Dilution solvent used during a print run was directly measured by volume.

After evaluating the field procedure and test results, it was decided that this was not a good approach. It was very difficult to accurately keep track of all the inks and dilution solvents used, especially for multi-colored runs. The recordkeeping required was quite extensive. Many Method 24 analyses were required. Small errors in the volume or weight determinations of the liquid ink would lead to large discrepancies with the gaseous part of the material balance. The results from this liquid material balance part of the test were inconsistent, and the approach is not recommended.

to large discrepancies with the gaseous part of the material balance. The results from this liquid material balance part of the test were inconsistent, and the approach is not recommended.

D.3 MONITORING SYSTEMS AND DEVICES

The recommended performance test for this regulation includes the determination of VOC control system efficiency. The overall VOC control system is composed of two parts: vapor capture system, and vapor processing device. The two types of processing devices that are expected to be used in this industry are carbon adsorbers and incinerators. Possible monitoring approaches and philosophy for each part of the VOC control system are discussed below.

The purpose of monitoring is to ensure that an emission control system is being properly operated and maintained after the performance test. One can either directly monitor the regulated pollutant, or instead, monitor an operational parameter of the emission control system. The aim is to select a relatively inexpensive and simple method that will indicate that the facility is operating as it did during the last successful performance test.

D.3.1 Monitoring of Vapor Processing Devices

There are presently no demonstrated continuous monitoring systems commercially available which monitor vapor processor operation in terms of efficiency. This monitoring would require measuring not only inlet and exhaust VOC concentrations, but also inlet and exhaust volumetric flow rates. An overall cost for a complete monitoring is difficult to estimate due to the number of component combinations possible. The purchase and installation cost of an entire monitoring system (including VOC concentration monitors, flow measurement devices, recording devices, and automatic data reduction) is estimated to be $25,000. Operating costs are estimated at $25,000 per year. Thus, monitoring in terms of efficiency is not recommended due to the potentially high cost and lack of a demonstrated monitoring system.

Monitoring equipment, however, is commercially available to monitor the operational or process variables associated with vapor control system operation. The variable which would yield the best indication of system operation is VOC concentration at the processor outlet. Extremely accurate measurements would not be required if the purpose of the monitoring is to indicate operational and maintenance practicies regarding the vapor processor. Thus, the accuracy of FIA (Method 25A) type instrument would not be needed. Less accurate, less costly instruments which use different detection principles are acceptable. Monitors for this type of continuous VOC measurement, including a continuous recorder, typically cost about $6,000 to purchase and install, and $6,000 annually to calibrate, operate, maintain, and reduce the data. To achieve representative VOC concentration measurements at the processor outlet, the concentration monitoring device should be installed in the exhaust vent at least two equivalent stack diameters from the exit point, and protected from any interferences due to wind, weather, or other processes.

For carbon adsorbers, the recommended monitoring approach is the use of a continuous VOC exhaust concentration monitor as discussed above. The EPA does not currently have any experience with continuous monitoring of VOC exhaust concentration of carbon adsorbers in the FVC&P industry. Therefore, performance specifications for the sensing instruments cannot be recommended at this time. Examples of such specifications that were developed for sulfur dioxide and nitrogen oxides continuous instrument systems can be found in Appendix B of 40 CFR 60 (Federal Register, September 11, 1974).

For some vapor processing systems, monitoring of another process parameter may yield as accurate an indication of system operation as the exhaust VOC concentration. Because control system design is constantly changing and being upgraded in this industry, all acceptable process parameters for all systems cannot be specified. Substituting the monitoring of vapor processing system process parameters for the monitoring of exhaust VOC concentration is valid and acceptable if it can be demonstrated that the value of the process parameter is indicative of proper operation of the processing system. Monitoring of any such parameters would have to be approved by enforcement officials on a case-by-case basis. Parameter monitoring equipment would typically cost about $3,000 plus $3,000 annually to operate, maintain, periodically calibrate, and reduce the data into the desired format.

For incineration devices, the exhaust concentration is quite low and is difficult to measure accurately with the inexpensive VOC monitors.

Instead, the firebox temperature has been identified and demonstrated to be a process parameter which reflects level of emissions from the device. Thus, temperature monitoring is the recommended monitoring approach for incineration control devices. Since a temperature monitor is usually included as a standard feature for incinerators, it is expected that this monitoring requirement will not incur additional costs for the plant. The cost of purchasing, installing, and operating an accurate temperature measurement device and recorder is estimated at $1,500.

The use of monitoring data is the same regardless of whether the VOC outlet concentration or an operational parameter is selected to be monitored. Continual surveillance is achieved by comparing the monitored value of the concentration or parameter to the value which occurred during the last successful performance test, or alternatively, to a preselected value which is indicative of good operation. A high monitoring value does not positively confirm that the facility is out of compliance; instead, it indicates that the emission control system is operating in a different manner than during the last successful performance test.

The averaging time for monitoring purposes should be related to the time period for the performance test. Since the recommended performance test for the FVC&P industry consists of three runs, each lasting from 1/2 to 3 hours, the length of an entire performance test may vary from 1-1/2 to 9 hours. Thus, 3 hours is recommended as the averaging time period for monitoring purposes.

D.3.2 Monitoring of Vapor Capture Systems

Monitoring the efficiency of a vapor capture system would be a difficult and costly procedure. This would require measuring the VOC concentration and volumetric flow rate in the inlet to the control device and in each fugitive VOC vent. Such a monitoring system has not been commercially demonstrated. The purchase and installation of an entire monitoring system is estimated at $12,500 per stack, with an additional $12,500 per stack per year for operation and maintenance. Thus, monitoring hood efficiency is not recommended.

As an alternative, an operational parameter could be monitored. The key to a good capture system is maintaining proper flow rates in each vent. Monitoring equipment is commercially available which could monitor these flow rate parameters. Flow rate monitoring equipment for each vent would typically cost about $3,000 plus $3,000 annually to operate, maintain, periodically calibrate, and reduce the data into the desired format.

Proper flow rates and air distribution in a vapor system could also be ensured by an inspection and maintenance program, which generally would not create any additional cost burden for a plant. The additional value of information provided by flow rate monitors would probably be minimal. Thus, it is recommended that no formal monitoring of the air distribution system be required. Instead, routine visual inspections of the fan's operation would indicate whether or not capture efficiencies remain at the performance test level.

D.3.3 Monitoring of Inks

If a plant elects to use low-solvent content inks in lieu of control devices, then the VOC content of the inks should be monitored. There is no simplified way to do this. The recommended monitoring procedure is to keep records of the VOC content and amount of each ink used and calculate the weighted average VOC content over the time period specified in the regulation.

Appendix E

MANUFACTURERS IDENTIFIED THAT POTENTIALLY COAT OR PRINT FLEXIBLE VINYL SHEET MATERIAL

Company Name	Plant Location
ABC Backing Corp.	St. Louis, MO
Acme Backing Corp.	Stamford, CT
Aladan Plastics Company, Inc.	Philadelphia, PA
Alltex Laminating Corp.	Mt. Vernon, NY
Alpha Associates Inc.	Woodbridge, NC
ALU Textile Combining Corp.	Hoboken, NJ
American Waterproofing	New Haven, MO
Apex Plastics Industries	Hauppauge, NY
Armco, Inc.	Middletown, OH
Athol Manufacturing Corp.	Butner, NC
Barley Earhart Corp.	Portland, MI
B.F. Goodrich	Akron, OH
Biddeford Industries	Biddeford, ME
BLP Inc.	Pulasi, VA
Borden Coated Fabrics	Columbus, OH
Breneman, Inc.	Oswego, NY
Bryant Industries Inc.	Paterson, NJ
Buckeye Fabric Finishing	Coschocton, OH
Carrier Corp.	Syracuse, NY
Chelsea Industries Inc.	Boston, MA
Chrysler Plastic Products	Sandusky, OH
Cinderella Clothing Ind.	King of Prussia, PA
Coaters, Inc.	New Bedford, MA
Colorama, Inc.	Paterson, NJ
Columbia Leather & Coating	Kenilworth, NJ
Commercial Vinyls, Inc.	New Castle, IN
Compo Industries	Waltham, MA
Craft Laminating & Backing Co.	Sowyersville, PA
Custom Coating Products, Inc.	Paterson, NJ
Custom Laminations, Inc.	Paterson, NJ

Appendix E
(Continued)

Company Name	Plant Location
Dal Bac Manufacturing	Forney, TX
Dayco Inc.	Dayton, OH
Detroit Body Products Co.	Wixom, MI
Duracote Corporation	Ravenna, OH
Engineered Yarns	Coventry, RI
Excello Fabric Finishes	Coshocton, OH
FAB Industries, Inc.	New York, NY
Farrington Texol Corp.	Walpole, MA
Ferro Corporation	Norwalk, CT
Flexfirm Products	El Monte, CA
Flexicota Processing Company	Clifton, NJ
Flex Tex Corp.	Chelsea, MA
Ford Motor Company	Dearborn, MI
Garden State Laminating Co.	Paterson, NJ
General Tire & Rubber Company	Reading and Lawrence, MA; Toledo, OH; Columbus, MS; Salem, NH; and Jeannette, PA
General Motors	Dearborn, MI
Georgia Bonded Fibers	Buena Vista, VA
Graniteville Company Woodhead	Graniteville, SC
qreater City Textile Company	Long Island City, NY
Great Lakes Paper Compnay, Inc.	Chicago, IL
Griffolyn Feef Industries	Houston, TX
Guilford Mills, Inc.	Greensboro, NC
Gustave Rubber Inc.	Bronx, NY
Haartz Auto Fabric Company	Action, MA
Hardwick Laminators	Harkwick, MA
Harte & Co. -Diamond Shamrock	New Yrok, NY
Hub Fabric Leather Company	Everett, MA
Jewell-Sheen Coating Inc.	Long Island City, NY
Joanna Western Mills Company	Chicago, IL

Appendix E

(Continued)

Company Name	Plant Location
John Boyle & Compnay Inc.	Statesville, NC
John Schneller & Associates	Kent, OH
Kellwood Company	St. Louis, MO
Lakeville Laminating	Fairfield, NJ
Lockwood Industries	Van Nuys, CA
Manning Fabrics Inc.	St. Pauls, NC
Masland Duraleather Co.	Mishawaka, IN
McGrew Color Graphics	Kansas City, MO
Microfibres Inc.	Pawtucket, RI
Oak Industries Inc.	Crystal Lake, IL
Pacesetter Products Inc.	Salem, MA
Pandel-Bradford	Lowell, MA
Pantasote	Greenwich, CT
Perforating Industries Inc.	Linden, NJ
Pervel Idustries, Inc.	Stratford, CT
Plever Industries, Inc	Carlstadt, NJ
PRF Corporation	New York, NY
Pyrotex Corporation	Leombusterm, MA
Realspan Corporation	Hickory, NC
Reliable Coated Fabrics Company	New York, NY
R.J.Liebe Athletic Lettering	St. Louis, MO
Rockland Bamberg Industries	Bamberg, SC
Rudd Plastic Fabrics Corp.	Brooklyn, NY
Selecta Finishing	Calhoun, GA
Seton Company	Newark, NJ
Shelter-Rite	Millersburg, OH
Silver Star Fabrics Corp.	Clifton, NJ
Sourthbridge Plastics	Clifton, NJ
Sourthern Bonded, Inc.	Henderson, NC
S and S Backing Inc.	St. Louis, MO
Standard Coated Products	Haxelton, PA

Appendix E
(Continued)

Company Name	Plant Location
Standard Shade Roller	Ogdensburg, NY
Star-Tex Industries, Inc.	Newburgport, MA
Stauffer Chemical Company	Newburgh, NY Westport, CT
Stedfast Rubber Co., Inc.	North Easton, MA
Synthon, Inc.	Cambridge, MA
Texon, Inc.	Sourth Hadley, MA
Thermopatch Corporation	Bronx, NY
Tuff Kote Inc.	Warren, MI
Uniroyal, Inc.	Mishawaka, In Port Clinton, OH Stoughton, WI
United Chemicals Inc.	Providence, RI
United Processing Corporation	Hawthorne, NJ
U.S. Plymeric Chemicals	Santa Ana, CA
Vulpex Inc.	Bellmore, NY
Wall Mates Vinyl, Inc.	Bellmore, NY
Wendell Testiles Shirt Hug	Essex, NJ
Weymouth Art Leather Company	Braintree, MA
Whitman Products Limited	West Warwick, RI

Sources: The 1980 Thomas Register; Economic Information System Plants Data Base; Chemical Fabrics and Film Association.

Appendix F

COMPUTATION OF GROWTH RATE

The growth rate for the value of shipments of supported vinyl materials over the 1971-1979 period may be obtained by employing the following methodology:

1. Compute a trend line for the value of shipments:

Year (N)	Value of Shipments (In Millions) (Y)	Time Period (X)	XY	X^2
1971	$ 488.90	-2	- 977.8	4
1973	664.60	-1	- 664.6	1
1975	607.20	0	0	0
1977	760.50	+1	760.5	1
1979	702.10	+2	1,404.2	4
	$\Sigma Y = 3{,}223.30$	$\Sigma X = 0$	$\Sigma XY = 522.3$	$\Sigma X^2 = 10$

$$\hat{a} = \frac{\Sigma Y}{N} = \frac{3{,}223.30}{5} = 644.66$$

$$\hat{b} = \frac{\Sigma XY}{\Sigma X^2} = \frac{522.3}{10} = +52.23$$

$$\hat{Y} = 644.66 + 52.23\,X$$

Base Year: 1975

Y = value of shipments of supported vinyl materials in millions of dollars

X unit = two years

2. Compute the estimated values (Y) for 1971 and 1979:

$\hat{Y}_{1971} = 644.66 + 52.23(-2) = 540.20$

$\hat{Y}_{1979} = 644.66 + 52.23(+2) = 749.12$

3. Compute the compound growth rate for the 1971-1979 period implied by the trend line:

$$G = \left(\frac{X_n}{X_1}\right)^{\frac{1}{n}}$$

where G = compound growth multiplier

X_n = the value of X in time period n

X_1 = the value of X in time period 1

n = the length of the time period*

The compound growth rate (C) can then be found by:

$$C = G - 1$$

For example,

$$G = \left(\frac{749.12}{540.20}\right)^{\frac{1}{9}}$$

$$G = (1.3867)^{\frac{1}{9}}$$

---

*The length of the time period 1971-1979 is nine (9) years rather than eight (8) years because the start of the period is January 1971, so that the entire year 1971 is included.

$$\text{Log } G = \frac{1}{9}(\text{Log } 1.3867)$$

$$= \frac{1}{9}(0.141997)$$

$$= 0.015777$$

$$G = \text{Antilog } 0.015777$$

$$= 1.03699$$

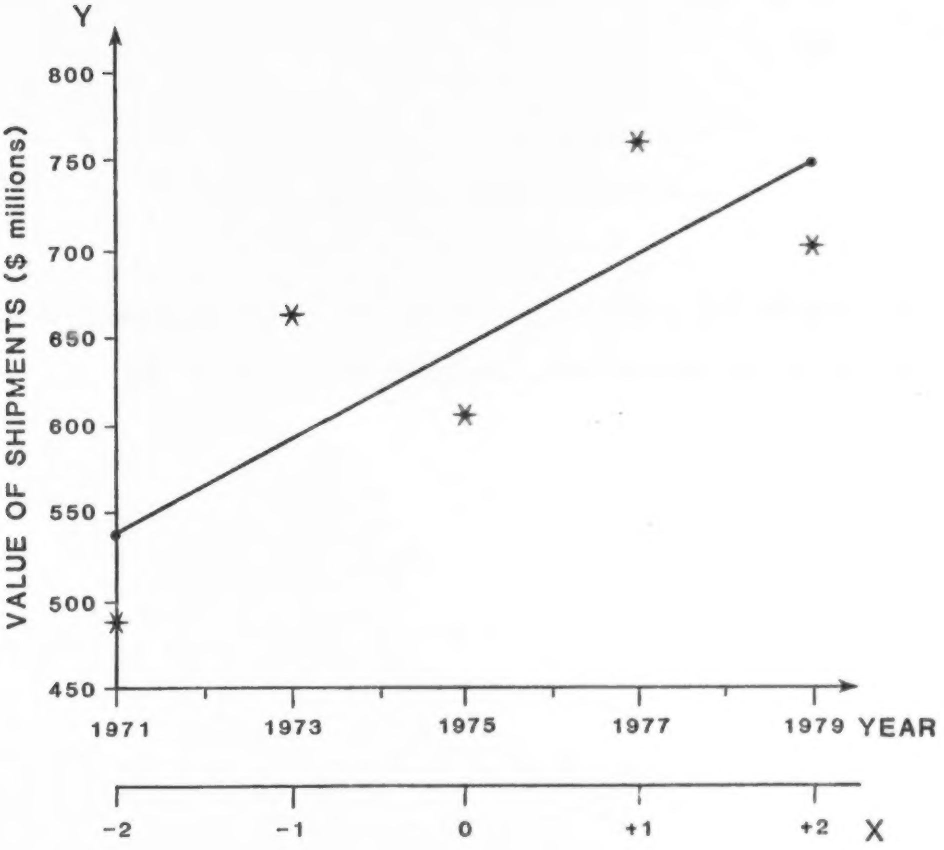
and

$$C = 1.03699 - 1$$

$$= 0.03699 \text{ or } 3.7\% \text{ per annum}$$

Figure F-1 graphically portrays the estimated trend line along with the actual observations, which are denoted by an (*).

Figure F-1.
Trend Line for the Value of Shipments of Supported Vinyl Materials in Millions of Dollars, 1971-1979.



Appendix G

FORMULA FOR DETERMINING THE PERCENTAGE CHANGE IN REAL OUTPUT

$$TR_0 = P_0 Q_0$$

where TR_0 = total revenue in some base period

P_0 = price

Q_0 = quantity

$$TR_0 + \Delta TR = (P_0 + \Delta P)(Q_0 + \Delta Q)$$

$$\frac{TR_0 + \Delta TR}{TR_0} = \frac{(P + \Delta P)(Q_0 + \Delta Q)}{TR_0}$$

$$1 + \frac{\Delta TR}{TR_0} = \frac{(P_0 + \Delta P)(Q_0 + \Delta Q)}{P_0 Q_0}$$

$$1 + \frac{\Delta TR}{TR_0} = \left(1 + \frac{\Delta P}{P_0}\right)\left(1 + \frac{\Delta Q}{Q_0}\right)$$

$$1 + \frac{\Delta Q}{Q_0} = \frac{1 + \frac{\Delta TR}{TR_0}}{1 + \frac{\Delta P}{P_0}}$$

$$\text{\% change in real output} = \frac{\Delta Q}{Q_0} = \frac{1 + \frac{\Delta TR}{TR_0}}{1 + \frac{\Delta P}{P_0}} - 1$$

Example:

Given that supported vinyl materials (excluding wall coverings) experienced a 3.7% annual growth rate in value of shipments over the 1971-79 period and that the price index for apparel experienced a 4.2% annual advance, then the percentage change in real output over the period was:

$$\frac{\Delta Q}{Q_o} = \frac{1 + \frac{\Delta TR}{TR_o}}{1 + \frac{\Delta P}{P_o}} - 1$$

$$= \frac{1.037}{1.042} - 1$$

$$= 0.9952 - 1$$

$$= -.0048$$